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THE GEOLOGY
OF THE
WARMBAD DISTRICT
SOUTH WEST AFRICA

An Explanation of Geological Sheets Amib (H-33-F), Umeis (H-34-A) and Nakop (H-34-B)

By

S. H. HAUGHTON, B.A., D.Sc., F.G.S.,
Director, Geological Survey of the Union of South Africa

and

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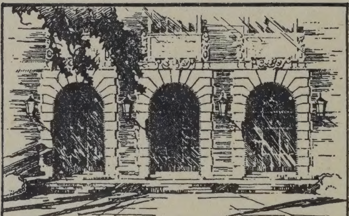
Geological Survey of the Union of South Africa.



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SOUTH WEST AFRICA

DEPARTMENT OF MINES

Memoir No. II

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The Secretary for South West Africa,
Windhoek

Sir,

I have the honour to submit the following report on the Geology of the Warmbad District — Memoir No. 2, S.W.A. — written by Dr. S. H. Haughton and Mr. H. F. Frommurze.

The report covers an area in the most southerly portion of the Territory extending from the Union border on the East to the mouth of the Fish River on the West, comprising the geological sheets Amib (SH-33-F), Umeis (SH-34-A) and Nakop (SH-34-B) of South West Africa.

The field work was carried out by the authors during the field seasons 1926 and 1927 with the primary object of establishing the general geological structure of this area. The work, therefore, is more in the nature of a reconnaissance than a detailed survey.

Portions of the chapter on Mineral Occurrences dealing with beryl, corundum, fluorspar and rose quartz have since been added by Dr. W. P. de Kock, until recently the Mining Authority of this Territory, and the whole chapter will be found of considerable interest.

As the area represented on the three sheets is still economically undeveloped it is hoped that the Memoir will prove of interest to the public generally as well as to those interested in the structure and geology.

The authors, all of whom have since severed their connection with the Administration, are to be congratulated on their clear and concise mapping and description of an area containing a number of complex rock-types.

The delay in publishing the results of the investigation is to be regretted but has unavoidably been due to various factors, chiefly owing to financial stringency.

I have the honour to be,

Sir,

Your obedient servant,

J. F. SCHROEDER,
Acting Mining Authority.

Mines Department,
Windhoek, 19th March, 1936.

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CHAPTER I.

INTRODUCTION AND PHYSIOGRAPHY.

The area described in the following pages is that portion of the Warmbad District of South West Africa bounded on the north by the railway line and stretching southwards to the Orange River. It was geologically surveyed in 1926 and 1927 by the writers who, for guidance and consultation, had the work of Dr. P. Range, "Geologie des deutschen Namalandes", and two papers by Dr. W. Versfeld in the "South African Journal of Science". The western boundary is the lower part of the Great Fish River, and the southern the Orange River; but some stretches along the Orange River were not examined on account of the difficulty of access. Reference is made in these pages to the neighbouring part of Namaqualand surveyed by Dr. A. W. Rogers and to a portion of Gordonia surveyed in 1925 by the senior author.

The main object of the survey was the elucidation of the general geological structure of the area, and time did not permit either of a detailed investigation of the mineral resources of the area (with the exception of the lead-bearing district of Aiais) nor of the detailed mapping of the pre-Nama granites, gneisses, and metamorphosed sediments. Although, as will be seen in the sequel, these pre-Nama rocks display an almost bewildering variety of types they have been mapped as a unit under the heading of "Granites, Gneisses, Schists, and Associated Rocks" except for those sediments which can be definitely correlated with the Stinkfontein and Numees series of Namaqualand.

The greater portion of the area is a plain of erosion sloping southwards to the Orange River. In the east, however, there is a "step" in this plain with a rise of some 600 feet caused by the escarpment capped by the lowest beds of the Nama system; whilst in the west there is a mountainous tract of country which culminates in the points Dreikopf (or Driekop) 3477 feet high and Chamgabmund 3877 feet high. Near the Orange River, where the older gneisses and granites are exposed, the plain is highly dissected and almost unoccupied.

The area is a barren one, with a low rainfall. With the exception of the Orange, which runs mainly in a deep valley between rocky walls, there is no perennial stream. There are but few spruits and many of the boreholes sunk have proved unsuccessful. Much of the little water obtained is salty; and the district is very sparsely inhabited. The centre of the Magistracy is the little village of Warmbad, which is some 30 miles by road from the railway at Kalkfontein. There is practically no agriculture in the area; the farmers have chiefly confined their attention to both Merino and Afrikander sheep and as a sheep-breeding country it has proved itself.

The Great Fish River is not perennial; but water can be found in it for most of the year. In its lower reaches it runs, like the Orange, in a narrow valley between high rocky walls, with every appearance of being an entrenched meandering stream. The other tributaries of the Orange to the east are of a different nature. They are all autochthonous to the area. In the country covered by the Karroo Beds the valleys are broad, open, and sand-filled; in the older rocks near the Orange the valleys are in the nature of poorts. The Geinab, like the Bak River in Gordonia, has cut a deep gorge down through the Blydeverwacht (Nama) Plateau. No waterfalls occur in the river-courses, so that grading of these stream-beds has progressed further than in the case of the Molopo; but the grade seems to be somewhat higher in the last mile or so before the tributary joins the Orange.

It is possible to divide the area into three parts. Along the Orange River and in the west the older rocks (gneisses, granite, etc.) form highly dissected, hilly tracts diversified by patches of sand. In the north and north-east the flat-lying Nama beds form a plateau which is continued eastwards into Gordonia. This plateau is largely covered by angular blocks and pieces of tough Kuibis quartzite which are of irregular size and shape and lie so close to one another that to travel over the area involves considerable discomfort. The vegetation here is very sparse and consists largely of melkbos (*Euphorbia* sp.). The third division lies roughly between these two in the centre of the district, and carries the most abundant vegetation. It is composed almost entirely of beds belonging to the lower part of the Karroo system with intrusive sheets of dolerite. The latter are in part less easily weathered than the sediments and give rise to isolated hills and ridges standing up from the general plain. The most striking of these are the isolated Eisenberg west of Haib, and the Amibberg north of Viol's Drift.

CHAPTER II.

1. GEOLOGICAL FORMATIONS.

The following shews in tabular form the various geological formations and intrusive rocks encountered in the area:—

Post-Karroo gravels and sands.

Karroo System	Ecca Series	
	Dwyka Series	Upper Shales Tillite.

Nama System	Schwarzkalk Kuibis Series.

Konkip (?) System	Numees Series. Stinkfontein Series.

Granites, Gneisses, Schists and Associated Rocks.

Intrusive Rocks	Dolerite, intrusive into Karroo Beds. Plug-like Intrusions. Dykes — pre-Nama.

2. THE GRANITES, GNEISSES, SCHISTS AND ASSOCIATED ROCKS.

In the eastern portion of Warmbad District these rocks underlie a large tract of country, situated south of the escarpment of Kuibis quartzites and basal beds, which extends from the Union border to west of the mouth of the Haib River, east of Viol's Drift on the Orange River. Their northern boundary, where they are covered by either the Karroo or Nama series, forms an irregular line westwards from a point about two miles north of the Orange River on the Union Border to Dreihuk in the Bondels Reserve, after which it assumes a southerly trend past Tsacharaibes down to near Viol's Drift, a distance of about 145 miles. The southern boundary is the Orange River.

In the west is a long strip of country where these rocks are exposed extending from Klein Karas in the north down to Nabas on the Orange River encompassing the farms called Frankfort 7, Kanebis 5, Kuduberg 9, Altdoorn 4, Wetterkop 12, and portions of Lubeck 2, Gaibes 1, Geiaus 6, most of the mining area of Aiais, portions of the Fish River valley and the high ground to the west of the Chamgab River. On the east they are covered by the Karroo beds and to the west by the Nama beds. A large part of this tract of country lies to the north of Sheet Amib (H—33—F.).

North of the main boundary of the eastern exposure are many large and small inliers in Nama and Karroo beds chief of which are those at Witkop 36, Nakop 68, Ukamas, Klein Aub 52 and Kalkfontein.

Extending across the river from the main body in Namaqualand is a further exposure in the form of a long narrow strip between Klipneus and Kwabs Drift on the Orange. This is covered to the north and east by beds belonging to the Karroo and Nama series.

The narrow and deep erosion kloofs on Border 155, Platrand 154, Blydeverwacht 72, Kentucky 80 and that in which the Ham River runs forming the boundary between Tsamab 57 and Gründorn 57 have all cut through the basal beds of the Kuibis series exposing the granites, schists and gneisses below.

The country underlain by these old rocks consists in the east of vast, sandy treeless plains, covered by Bushman or Toa grass. On the flat surface on these plains outcrops of rock are rare and the only indication of the underlying stratum is to be found in the coarse rock debris or gravel lying about, the arid climate prevailing in this district favouring the formation of the latter.

The only outstanding features seen here are the small hills formed by the ancient intrusives into these old rocks. These low dark coloured masses such as Einsiedler, Velloorkuppen, and Haiber Kuppe form prominent landmarks which can be seen for miles in every direction. Although apparently horizontal the surfaces of these plains dip gently towards the Orange River; where, however, the tributaries of the Orange River have by virtue of their erosive powers dissected the plain, hills and flats of granite, gneisses, schists and altered sediments are exposed in all their varieties. This condition exists along the courses of Hom, Ham, Velloor and Blydeverwacht Rivers, and on a grander scale in the valleys of the Chamgab, Fish and the Orange itself.

Although this large area underlain by these rocks was not examined in great detail, they can be subdivided as follows:—(q.v. Wagner G.S.M. 7).

Gneiss and Schist formation.
Intrusive older and younger Granites.

The various types of gneiss occupy the major portion of the area, the schist formation being quite subordinate and the intrusive granite scarce.

The Eastern Portion:

Situated on the boundary between Witkop 36, Ukamas 69 and Nababis 70, is an area of granites and schists surrounded by Kuibis beds; the greater part of the exposure is on Witkop 36.

The rocks occupy a large amphitheatre-like depression which is about 100 feet below the level of the country to the north.

In the northern portion of this exposure is a peculiar rock. It is fine-grained, dark in colour, and is studded with large and small irregular shaped porphyritic crystals or inclusions. These latter are both light and dark coloured; and they have peculiar zoned reaction rims, appearing as though some resorption had taken place. Lying next to the above and partly separating it from a granulite ridge to the south is a long narrow body of intrusive hornblende granite. A long ridge of black garnet-sillimanite granulites extends right across the area, a distance of about five miles.

South of this ridge are hills of light coloured gneissic rocks containing sillimanite and tourmaline and interbedded with them are thin bands of sheared amygdaloidal rocks. Standing isolated towards the south-eastern corner of the inlier is a striking hill of white rock from which the farm derives its name; this proved to be a pegmatite.

These rocks all strike in the same direction, NW—SE, and seem to be continuous with the small exposures in the kloof to the north of Ariams Vlei on Ukamas, where they strike 20° N. of E. and dip to the SW.

To the south of Witkop the same series of rocks is seen below the Kuibis quartzites in the kloof on Platrand 154 where gneisses with thin bands of amygdaloidal rocks occur. Here the gneiss is considerably coarser than on Witkop, and garnet granulites play a much less important part in the succession. Tourmaline-bearing pegmatites and veins of rose-quartz cut the metamorphic rocks in this area.

Towards the southern corner beacon along the Ukamas 69—Nakop 68 boundary is another inlier of old rocks. Many varieties are represented here, garnet-sillimanite gneisses occurring in the western portion, while on the eastern side are dark garnetiferous granulites with intrusive coarse-grained granite, and bands of dark blue-grey amygdaloidal rock, carrying garnets and interbedded with light coloured garnet gneisses.

At Blydeverwacht 72 most of the rock encountered is a fine-grained gneiss of a non-garnetiferous variety. Cutting through this rock and forming a low black hill is a long narrow band of black hornblende rock (amphibolite) running almost due north and south. This band crosses the boundary into Jerusalem 73 and continues down to the settlement of Jerusalem. The fine-grained gneisses merge imperceptibly into coarser-grained varieties to the south and these in turn give place to darker varieties (the darkening of colour being due to the addition of biotite) carrying an abundance of garnets and some sillimanite. At the settlement of Jerusalem a schistose aplitic rock is interbedded with the gneiss; it dips to the east at 45°. An extraordinary feature noticed here was the presence of thin limestone veins, sometimes composite, cutting across the gneisses and amphibolites. These veins were from 2″ to about one foot thick.

In the embayment below Rand Trig. beacon and at the cross-roads below Kentucky kloof garnet-sillimanite gneisses outcrop. At the latter locality the rock is dark coloured, micaceous and contains garnets measuring 1—2″ in length.

Most of the rock outcropping in the Kentucky kloof is garnetiferous gneiss, but a narrow band of garnet-sillimanite rock extends across the Kloof in a north-westerly direction.

At the homestead a well has penetrated a soft green epidote gneiss and a harder pink coloured variety which contains piedmontite. These rocks were seen in debris removed from a well on Vlissingen 59 some 5 or 6 miles to the north. On Vlissingen these peculiar rocks are underlying some 60—70 feet of Kuibis beds thus proving the subsurface extension of these bodies of altered sediments.

On Hogeis 83 and continuous on to Bokkiesbank West 82 are bodies of hornblende granulites amidst the coarse porphyritic gneiss and granites of this locality. The granulites form irregular shaped masses and are associated with hornblende-biotite rocks, dark grey amygdaloids, red epidotic quartzites, and a light coloured fine-grained acid granite. The granulites strike in a north-westerly direction and dip at a high angle to the south-west.

To the north-east of the above and situated on Bokiesbank Ost 79 are two narrow bands of dark biotite schists, hornblende granulites and altered amygdaloids. These cross the farm in a NW—SE direction.

Peculiar limestone veins similar to those seen on Blydeverwacht were found here. They strike practically due E. and W. and on either side are narrow pegmatites with brickred felspars. The veins are thicker here, about 18″ to 2′ thick and are often bent and folded and sometimes broken by minor faulting. They are generally fine-grained but occasionally a coarse grain was seen; where fine-grained they weather to a rusty brown, but the coarse grained varieties remain grey. The veins are sometimes zoned, the central portion containing inclusions of angular felspar, quartz, mica, and galena fragments.

Where the course of the Ham River leaves the Kloof dissecting the plateau on Tsamab 57 three ancient amphibolite dykes occur cutting the porphyritic and garnetiferous gneisses. Running in a NW—SE direction they cross the bed of the river and disappear under the Kuibis beds at their junction with the gneiss.

At the homestead on Velloor 89 about 15 miles to the south of Bokiesbank West are further outcrops of dark coloured rocks in the gneisses and schists. A small black kopje on the river bank west of the house is formed by a coarsely crystalline hornblende diorite. Dipping in the same direction as the gneisses it crosses the river and disappears just east of the house. In the river bed it has a porphyritic structure, containing large hornblende crystals.

South of the Velloor homestead about 6 miles down the river is a large rounded exposure, measuring about 2 miles across, of banded granulites and biotite schists forming a perfect anticline from N—S. From here down to the Orange River are banded non-garnetiferous brown-weathering gneisses.

North of the homestead and dipping at about 20° to the north is a narrow band of epidote and quartz granulites, prominent among which is a rock with large pale green porphyritic crystals; surrounding these are coarse grained porphyritic gneisses.

West of the house, at the Bank-Velloor beacon, are quartz and biotite schists carrying garnets and narrow bands of amphibolites and diorites. All these are standing practically horizontal in fine-grained non-garnetiferous gneisses.

Still further to the west along the road to Warmbad, standing alone in the centre of a large flat sandy plain, are the five small black hills where Velloor Kuppen trig. beacon is placed. Another outstanding black hill on this plain formed from the same rock is Einsiedler situated 15 miles to the NW. of the above hills. Similar lithologically and in formation is Haiber Kuppe situated in the Bondels Reserve 27 miles NW. of Einsiedler.

These hills, although small, are very prominent owing to the flat nature of the neighbouring country and can be seen for miles in all directions. They all have beacons on their summits.

Einsiedler has two varieties of rock building it, a grey hornblende granulite resting on the gneiss forming the basal portion of the hill, and lying on this and forming the upper portion is a black weathering hornblende diorite.

At Velloor Kuppen and Haiber Kuppe, however, only the black weathering variety occurs. These exposures seem to be remnants of a large intrusive sheet.

In the neighbourhood of Einsiedler are several bands of dark-coloured shining rocks which are occasionally amygdaloidal. They are associated with garnet granulites, altered limestones, and altered porphyries.

These altered igneous and sedimentary rocks occupy a fairly large area in this vicinity extending in a direction slightly north of west from Huniam West 117, past Einsiedler, across Ortmansbaum 125, Swarthuk 121, into the Bondels Reserve up to near Tsacharaibes, beyond which point they are covered by the Dwyka beds. They appear to be lithologically related to the granulites on Hogeis.

At Huniam West north of the homestead a narrow band of fine-grained blue-grey rock which occasionally develops amygdaloidal structure was observed. Striking E—W this band was found to be continuous for a distance of over twelve miles after which it was lost sight of in the Bondels Reserve. It dips to the north and seems to be the edge of a sheet.

South of the homestead on Huniam West are dark fine-grained garnet-bearing rocks.

To the south of the dioritic sheet at Ortmansbaum the altered sediments are associated with garnet-biotite gneiss and are surrounded by coarse-grained porphyritic gneiss. The dark granulites here occur together with very fine-grained white limestones which carry garnets.

The same series of dark granulites and associated rocks striking in a similar direction was observed at Bondels I beacon and near Haiber Kuppe beacon south of Tsacharaibes.

At Schönau 126 an outcrop of dark hornblende granulite carried an abundance of magnetite in the form of large crystals.

At Kalkfontein there is an occurrence of gneisses and schists as an inlier surrounded by Karroo beds. The gneisses are well-banded garnetiferous and non-garnetiferous varieties with veins of garnet-bearing pegmatites and aplites. To the north of the Police camp are bands of dark hornblende granulites striking north and south. The gneisses are cut by a sheet of dolerite. About 5 miles south of Kalkfontein at Bult Trig. beacon is another small inlier of gneiss.

At Warmbad township are non-garnetiferous gneisses. Near the bath house this rock has been invaded by fine-grained granite; both rocks are cut by pegmatite veins. To the north and north-west of the town the gneiss forms prominent hills and bands of amphibolites are interbedded. The strike is east to west but west of the town it changes to NW—SE.

At Haibpoort there are dark coloured volcanic rocks associated with the gneiss. These rocks have amygdales of blue quartz and dip at 70° to the south.

At Viol's Drift on the Orange River are large beds of green sheared volcanic rocks in the gneisses. There are also a number of small granite intrusions.

Similar lavas, intruded by biotite-granite, etc., have recently been mapped in detail by Dr. T. W. Gevers on the south bank of the Orange River in a zone stretching from near Viols Drift eastwards to Xochasib. There the lavas include two groups: (1) mainly schistose and flaggy lavas consisting of highly sheared greenstones, epidiorites and other diabasic lavas with intermediate and more acid types, the latter in the form of hälleflinta and platy quartzose rocks; (2) frequently highly amygdaloidal dark diabasic lavas. Gevers suggests that these belong to the Kheis system and may be representatives of the Wilgenhout Drift series of the Cape Province.

The Western Portion:

In the south the hilly country west of Kanibeam (near Marinkas Quellen and Agareibis) is formed of a steeply dipping series of gneisses, schists and granulites with a prominent band of altered limestone. The series strikes a little south of east and dips to the north at angles varying from 60° to 80°. Intruded into this is a plug of granite, pegmatitic in parts, containing numerous xenoliths.

The granite consists of quartz and microcline with subsidiary muscovite. From it veins of coarse pegmatite, some carrying black tourmaline, cut the gneisses and schists.

North of Kanibeam the older rocks are hornblende schists, biotite schists, etc., striking approximately E.S.E. and dipping at high angles. Intruded into them is a mass of fine-grained aplitic granite.

North of these are almost vertical green or white quartz schists, hornblende schists, and schistose cherty amygdaloidal rocks which are succeeded by sugary fine-grained felspathic quartzites and granulites, and these again by hornblende schists, mica schists, and fine-grained acid paragneiss. At Dreikopf and for some distance to the south the hills are formed of gneiss and gneissose granite. The schists and gneisses are cut by dykes of coarse-grained quartz-felspar pegmatite, which are presumably connected genetically with the granite stocks of the Kanibeam area.

At the Aiais hot spring in the Fish River dark argillaceous schists were seen.

The Granites.

The intrusive granite only occurs at a few localities, the most important exposures being those at Nakop 68, Border 155, Witkop 36, Warmbad 145, Bokiesbank W. 82, Schönau 126, Kanibeam, Agareibis and Chorab River.

The most prominent type is the granite at Nakop, Beacon 122, Border and at several places in this vicinity. It is a coarse-grained hornblende granite, sometimes foliated, and has large porphyritic felspar crystals. The porphyritic structure is the distinguishing character.

At beacon 122 on the S.W. Africa—Union border is an inlier of granite exposed in a stream bed; the granite is a coarse-grained variety with large porphyritic crystals of pink orthoclase and green plagioclase. It is foliated and colour banded in places and sometimes carries garnets. In the centre of this granite an outlier of Kuibis quartzite forms the summit of the hill on which the beacon stands.

Other localities where this same rock was observed as inliers were on either side of the road between Nakop and Ariams Vlei, at the border beacon near Nakop siding and in a well at the old house on Border 155, also where the Border farm road begins to descend into the kloof.

The material obtained from the well on Border showed as a very handsome rock, due to its freshness and the extraordinary development of the pink and green porphyritic felspars.

At Witkop 36 a fine-grained hornblende-biotite granite is intrusive in the schists.

At Bokiesbank W. a fine-grained acid granite with titanite occupies a fairly large area. A similar variety is seen in the gneiss near the bath house at Warmbad. At Hogeis a light-coloured granite was found which contained, in addition to titanite, a little pleochroic yellow augite (4973). From west of Kanibeam a light-coloured variety was seen which proved to be a muscovite-granite.

All the above granites are intrusive into the schists and gneisses but not into the Nama rocks which can be seen resting on the granite at several places.

The Gneisses.

A bewildering variety of lithological types falls into this division. The variety is in both structure and composition. Coarse-grained, fine-grained, porphyritic, banded and non-banded types are common, while with regard to composition, non-garnetiferous, garnetiferous, cordierite, sillimanite, and biotite gneisses all occur.

In the Kloof on Platrand 154 brown-weathering non-garnetiferous gneisses and fine-grained garnet gneisses with thin bands of amygdaloidal and blastoporphyritic rocks are seen. The fine-grained variety is typical of the garnet gneisses and on examination under the microscope (No. 4961) shows garnets with pleochroic haloes with quartz, orthoclase and pleochroic biotite; a little cordierite, apatite and zircon are present.

A mauve coloured schistose rock found in a prospecting pit on Witkop 36 showed in thin section (4958) to be composed almost entirely of fibrous aggregates of sillimanite with biotite and a little corundum.

There are exposed south of the road from Ukamas to Ariams Vlei inliers of garnet-sillimanite gneiss, and north of the road garnet-sillimanite granulites, granite, and a fine-grained gneiss which proved on microscopic examination to be a garnet-sillimanite-cordierite gneiss.

The peculiar soft green gneiss from the well on Kentucky 80 showed under the microscope (No. 4968) large masses of crystalline calcite, large feathery crystals and flakes of faintly pleochroic mica crowded with inclusions of iron-ore, epidote and orthoclase. The pink variety from the same locality showed (No. 4967) a lesser amount of orthoclase and mica, more epidote (some of which was piedmontite), large crystals of apatite, abundant iron ores and veins of secondary quartz and calcite.

Amphibolites, hornblende granulites, etc.

There are a number of rocks intrusive into the gneisses of varying ages which cannot exactly be determined; from the varying degrees of metamorphism they have undergone it is assumed that some are much older than others.

At Jerusalem occurs a long narrow outcrop of amphibolite or hornblende granulite which appears to have been a basic dyke. It is a dark glittering rock consisting almost entirely of hornblende and biotite.

At Einsiedler, Velloor Kuppen, Haiber Kuppe, the dark rocks appear to be the remnants of an ancient sheet intrusion. The grey rock showed under the microscope (4981) large plates of granular green hornblende (actinolite), muscovite, a little plagioclase, garnet, apatite and iron ore. The dark rock showed olivine and amphibole ophitically intergrown, plagioclase and a little brown biotite.

The sheet-like intrusion of diorite at the Velloor homestead is a rock fresh and unchanged and presumably younger than the altered varieties quoted above. A thin section cut from this rock showed decomposed plagioclase, a little orthoclase and green pleochroic hornblende altering in places to biotite.

Another sheet is seen north of the homestead on Huniam West. Thin section (4964) cut from this rock showed large irregular porphyritic crystals of quartz and plagioclase, smaller prisms of pale green slightly pleochroic hornblende, a little biotite and iron ore set in a ground mass of quartz, plagioclase and hornblende.

East of Haib an intrusive rock proved on examination (4979) to be a gabbro composed of plagioclase, augite and a little biotite, apatite and iron ores.

The altered sediments, schists, granulites and allied rocks.

The rocks which are treated here can probably be correlated with the Schist and Phyllite formation in South West Africa referred to by Wagner (G.S.M. No. 7) and the Kheis series of the Swaziland system in the Union.

The majority of the occurrences of these rocks to be referred to appear to be in the nature of large xenoliths in the gneissoid and granitic rock of the area, detached fragments or inliers from either the main bodies of the schist and phyllite formations in the north or from the Kheis series to the east in Gordonia.

The occurrence of so many small separate bodies as xenoliths or "float" naturally gives rise to a great variety of contact phenomena, such as the formation of mixed rocks, re-crystallisation, etc.

These rocks are found in the east at Witkop 36, Platrand 154, Nakop 68, Ukamas, Jerusalem 73, Blydeverwacht 72, Kentucky 80, Bokiesbank Ost 79, Hogeis 83, Bokiesbank West 82, Velloor 89, Nautsis 92, Huniam West 117, Ortmansbaum 125, Swarthuk 121, Warmbad 145, Schönau 126, Violsdrift, Haib Poort and in the Bondels Reserve east of Haib. In the west the occurrences appear to be of greater individual extent; they are to be seen at Agareibis and Kanebis.

This division has a long list of rock-types which go to form it, biotite schists, garnet-sillimanite schists, quartz granulites, hornblende granulites, garnet granulites, altered quartzites, altered limestones, altered porphyritic lavas, cordierite rocks, augite granulites, biotite-garnet-diopside rocks, and various other metamorphic varieties.

A description of some of the more common types follows forthwith:—

Three specimens collected from the long ridges of black garnet-sillimanite granulites on Witkop showed in thin section —

(1) No. 4955. Large relic crystals of altered plagioclase rimmed with biotite, large crystals of altered orthoclase containing needles of apatite, corroded crystals of garnet, biotite, zircon and iron ore. The granulitic mass is composed of plagioclase and biotite.

(2) No. 4956. Abundant large crystals of colourless and brown garnets, large crystals of orthoclase showing strain crowded with small inclusions and altering to a fibrous material, pleochroic biotite, numbers of fine needle-like prisms of sillimanite, a little cordierite and iron ore.

(3) No. 4957. Strained and crushed orthoclase, plagioclase, green mica containing small crystals of piedmontite, penninite, zircon, apatite and iron ore.

South of the homestead on Huniam West a dark finegrained garnet-bearing rock showed under the microscope (No. 4976) large crystals of felspar with diopside, garnet, biotite, zircon and iron ore.

A thin section (No. 4978) cut from a grey garnet rock with porphyritic structure at Ortmansbaum showed large irregular relic masses of strained orthoclase and plagioclase rimmed with a granulitised border and garnets with a finer grained ground mass of orthoclase, biotite, and a little plagioclase; small zircons were present.

A section cut from the dark hornblende granulite carrying magnetite at Schönau 126 showed orthoclase and plagioclase with green pleochroic hornblende, a little augite, apatite and magnetite.

Interbedded in many places with the granulites referred to in the previous section were many varieties of amygdaloidal rocks in various stages of metamorphism. These are apparently volcanic rocks which have been more or less altered.

A band of dark blue-grey amygdaloidal rock from the granulites occurring near the southern corner beacon on the Ukamas—Nakop 68 boundary showed on microscopic examination (No. 4960) orthoclase, plagioclase, quartz, augite, biotite and apatite; the amygdales were chiefly plagioclase.

A thin section (No. 4972) of the amygdaloidal rock occurring near Beacon 165 on Hogeis showed strained quartz amygdales, in which incipient granulitisation has begun, in a ground mass of plagioclase, quartz, green pleochroic hornblende, augite and calcite; a little epidote, apatite and zircon are present.

The amygdaloid from Bokiesbank Ost 79 showed (No. 4975) porphyritic crystals of altered orthoclase and plagioclase in a ground mass of plagioclase, green pleochroic biotite, chlorite, a little apatite, iron ore and zircon. Evidently an altered porphyritic lava.

A quartzite from beacon 165 at Hogeis is a fine-grained variety of red colour: under the microscope (No. 4971) it was found to be composed mainly of crystalline quartz and epidote, accompanying which was apatite and piedmontite. Another specimen from the same vicinity had a similar composition with the addition of chlorite and iron ore.

A band of limestone associated with the dark granulites on Ortmansbaum showed (No. 4977) crystalline calcite with garnets, quartz and apatite.

The marble occurring in the series of sediments in the kloof near Agareibis showed in thin section (No. 5049) recrystallised calcite, small grains of quartz, iron ores and apatite.

A section from the peculiar limestone veins from Blydeverwacht and Bokiesbank previously referred to, shows, set in a matrix of granular calcite, abundant large and small prisms of apatite, fragments of strained orthoclase showing secondary twinning, and a little limonite.

Intrusive dykes (pre-Nama).

The schistose rocks and the pegmatites are cut by numerous dykes of diabase, orthophyre, bostonite, etc., which are prominent features of the area and run in three different directions, — (a) 10° to 20° west to north, (b) 10° east of north, and (c) from 10° to 20° north of east.

The dykes are made up of several types of rocks.

1. Common are pinkish brown fine-grained silky or stony rocks which are comparable with the *bostonites* of Namaqualand and Van Rhyn's Dorp. The most typical consist of long phenocrysts of orthoclase sparsely set in a ground-mass of felted elongated laths of anorthoclase, with subsidiary iron ore and a fibrous pleochroic green mineral that seems to be a soda-pyroxene. Chlorite (var. penninite) is a decomposition product, along with calcite. Apatite is occasionally present. By the addition of a little interstitial quartz the rock approximates to a *quartz-bostonite.* One variety (S.W. 85) has the laths of the ground-mass showing fluidal structure, with small grains of green fibrous mica and secondary calcite filling amygdales. Another variety has the short stumpy felspars in the ground-mass that are more characteristic of camptonites.

2. Another type of dyke-rock is allied to the *camptonites.* The porphyritic crystals are of felspar and of a ferro-magnesian mineral (either augite or hornblende) which is altered to epidote and calcite and frequently surrounded by a rim of penninite. The ground-mass consists of laths of anorthoclase and of a plagioclase felspar, plates of brown pleochroic hornblende with a low extinction angle (probably barkevikite), abundant needless of apatite, a large amount of iron ore, opaque dusty whitish material that may be

leucoxene, and zircon. The felspar is largely decomposed, chlorite being abundant.

3. Of the quartz-bearing dykes, the commonest are *quartz porphyries.* One type of these has phenocrysts of orthoclase (altering to muscovite and calcite) and of slightly corroded quartz, set in a granular ground-mass of muscovite, quartz and orthoclase. Another type displays micrographic structure in the ground-mass, the micrographic intergrowths often forming borders to the orthoclase phenocrysts.

4. Another dyke rock may be called a *quartz-keratophyre.* It consists of phenocrysts of plagioclase felspar (albite) set in a fine-grained ground-mass of quartz and felspar with a small amount of greenish mica.

5. Finally there are dykes of *diabase.* One of these, from Ysterbank, shows laths of plagioclase set in a mass of titaniferous augite and iron ores, with calcite and chlorite appearing as decomposition products.

Pegmatites.

The area as a whole has been cut by a multitude of large and small pegmatite dykes. These dykes vary from 2 feet up to 30 or 40 feet in thickness and are composed of large crystals of pink or white felspar, sometimes both, quartz, tourmaline, and occasionally muscovite. Often the pink felspar has associated with it, perhaps as an alteration product, large masses of epidote of that peculiar green colour which is so typical of that mineral.* This gives the rock an exceedingly striking appearance.

These dykes form a characteristic feature of the country giving rise to long light-coloured strips and mounds of white quartz and pink felspar debris, which lies about in great quantities sometimes concealing the true nature of the rock beneath.

In the Fish River valley the pegmatites often consist wholly of rose quartz forming a striking feature in the dark paragneisses.

At Witkop is an outstanding hill of white colour which proved on examination to be almost all milky quartz with a few crystals of tourmaline and a little felspar.

The amphibolites on Jerusalem were associated with a coarse-grained pegmatite of white felspar and amethystine quartz.

On Hogeis thin pegmatites with brick red felspar occurred associated with the lead-bearing limestone veins.

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* Versfeld, W. The Geological Structure of Portions of German South West Africa. S.A. Journal Sci. March, 1915, p. 190.

3. KONKIP SYSTEM.

In his "Geology of Part of Namaqualand" Rogers (1915) described certain folded rocks in the west of Namaqualand as the correlatives of the Nama system under the name "Folded Nama" and grouped them into four series, called Stinkfontein, Kaigas, Numees, and Groot Derm. Recent work has shown that this succession is older than the Nama of the Neint Nababeep area, and the probability is that the rocks are to be correlated with the varied group of rocks older than the Nama and younger than the old gneiss to which Range gave the name of Konkip formation.

Patches of these rocks occur in the south⸗western corner of the Warmbad district; and although their interrelationships are there very obscure it is possible to place them in the series named by Rogers.

Stinkfontein Series. The mountains to the south of Klipneus on the Orange River are formed partly of the eastward continuation of the Stinkfontein beds of the TcOulyroup range of the Richtersveld. As in Namaqualand the beds consist mainly of thick quartzites which are mostly white in colour, fine⸗grained and crystalline. Some bands are dark blue in colour owing to the presence of finely divided magnetite; and magnetite in larger grains is also present in the white quartzites. Felspathic quartzites are not prominent. To the east the quartzites overlie coarse gneiss, but the nature of the junction is not obvious; at the places examined there is, between the gneiss and quartzites, a band of quartz schists and sheared gritty conglomerates.

Apparently overlying the quartzites to the south is a considerable thickness of green slaty rocks which appear to dip beneath the gneiss. The whole succession of quartzites is somewhat highly folded, and its boundaries must be, at least in parts, determined by faults. In the extreme eastern portion of their outcrop the quartzites rest on redweathering quartz porphyry which is obviously folded in with the quartzites. Where the quartzites dip steeply there is a sheared zone between the Stinkfontein sediments and the quartz porphyry.

The Kaigas series is not represented in the area. Beds belonging to the *Numees series* occur in close proximity to the Stinkfontein beds near the Chorab valley. North of the Chorab valley and west of the road from Viols Drift to Aussenkjer there is a prominent group of hills of which the highest carries a beacon. The main ridge of this group consists of a porphyritic granite of medium grain carrying green mica which is flanked on either side by red⸗ and white⸗weathering quartz porphyries. On the west side there is a succession of sediments dipping to the west. The base of these consists of a thick conglomerate. The matrix of this consists largely of pieces of felspar in which are set well⸗rounded pebbles and boulders of very varying size, composed mainly of gneiss but containing other rocks. In the conglomerate are bands of gravel, and occasionally the matrix becomes argillaceous and sheared, looking then exactly like the Numees tillite from the Richtersveld. Overlying this are blue-black slates with occasional pebbles; then follows a prominent band of grit with pebbles and finally a band of whitish quartzite. Both this series and the quartz porphyries are overlain unconformably by red Dwyka.

A few hundred yards to the north there is another magnificent exposure of this presumed Numees tillite. The beds contain some slate bands and lenses. The conglomerate contains numerous boulders, some of which are up to two feet in diameter. The largest usually consist of a coarse binary gneiss with pink felspar. Only one limestone boulder was seen here.

The Numees beds here and still further to the north-west rest on the quartz porphyry in the form of an elongate syncline. The conglomerates contain quartz porphyry pebbles. Part of the conglomerate has the general appearance of a coarse even-grained binary gneiss or granite with abundant felspar, but it contains numerous rounded pebbles and boulders, mostly of granite or quartz porphyry, but some of red quartzite, shale, slate, etc. Unfortunately this band weathers rather easily and the boulders drop out so readily that it is difficult to obtain specimens showing the pebbles in place.

Nowhere in this area is there any contact between the Stinkfontein and Numees beds. At one point they are separated by only a few hundred yards of quartz porphyry, with which both are in contact along apparently unconformable junctions. Whereas, however, the Numees beds are but moderately folded, the Stinkfontein quartzites are more highly folded and even overfolded.

The other locality at which rocks tentatively assigned to this system occur is near the mouth of the Chamgab river. There, folded Nieuwerust and Malmesbury beds are faulted against a series of sheared green grits, arkoses, green quartzites and conglomerates which are well seen along the left bank of the Chamgab, while along the Orange River section the beds also contain sheared green porphyritic rocks and felspathic schists, the latter weathering into soft reddish pink and white clays. Some of the conglomerates look like tillites and consist of an arenaceous matrix with pebbles of varying size and kind. One member of the sequence is a coarse torrential conglomerate containing numerous boulders of granite. On the west the beds are faulted against sheared gneisses. In a section on the right bank of the Chamgab, north of the entrance to the poort, the series of sheared green grits contains a thin band of tillite which is sheared and consists of a dark blue matrix with boulders, pebbles and small grains almost exactly similar to the sheared Numees tillite of the Richtersveld.

No exact parallel can be drawn between these rocks and either the Konkip beds of South West Africa or the Ventersdorp or Koras rocks of the Union; but the points of resemblance to all three are suggestive, and further detailed work in this area must throw much light on the correlations between these various groups of Pre-Nama rocks.

4. NAMA SYSTEM.

In Gordonia rocks belonging to the Nama system have been described by Rogers as Zwartmodder Beds, and no subdivision of them was attempted. In South West Africa Range divided the Nama system into an Upper division and a Lower division, further subdividing the latter into

(c) Schwarzkalk,
(b) Kuibis Beds,
(a) Basal Beds.

The work of the Survey carried out in 1925 and 1926 has shown that the Zwartmodder beds of Gordonia — excluding the outcrops near Sannah's Post, which have not been re-examined — are the equivalent of the Lower Nama of Range; and the latter name will, therefore, be used in this description. No distinction has been drawn on the map, however, between the Basal beds and the Kuibis beds; and the two will be treated as one subdivision.

North of the railway line between Noap Kop in the east and Nieuwefontein Siding on the west there is a very prominent denticulated escarpment. From Noap Kop westwards to Kums the top of this escarpment is formed of a somewhat massive red sandstone. As it is traced westwards from Nakop this sandstone becomes thinner; and west of Kums its place in the sequence is taken by a thin band of yellow limestone. This is the lowest horizon at which limestone occurs in the system and, in consequence, the base of the massive sandstone determining the escarpment and the base of its equivalent limestone in the west have been taken as the base of the Schwarzkalk. All the sediments lying between this horizon and the older granites and metamorphic rocks have been grouped together as the "Basal and Kuibis beds".

Basal and Kuibis Beds. The general features of these beds are well known. In the area under consideration the Basal beds usually consist of a few feet of reddish shale, followed by grits and rather fine conglomerates (sometimes containing jasper pebbles), and micaceous red flagstones with thin bands of shale. Following this general sequence are hard reddish-weathering grey or bluish quartzites which usually determine the lower plateau. These quartzites have subordinate bands of reddish and grey-green sandstone which — like the quartzites — are often distinctly current-bedded. The quartzites on weathering break into angular fragments which accumulate in great quantities at the surface and make the country which they occupy very barren and very difficult to traverse. Between them and the base of the Schwarzkalk there are some 250 feet of sandstones, flags and shales. The escarpment behind Nakop shows the following succession through this upper portion of the Kuibis beds:—

Massive red sandstone (base of Schwarzkalk)	
Soft red and green micaceous shales and flags	Upper part of Kuibis.
Quartzite	
Soft micaceous greenish shales	
Greenish sandstone	
Red and greenish sandy shales and sandstone	

The best sections through the basal portion of the beds occur south of the railway line between the Molopo river and the Ham river. Here the various tributaries of the Orange river have cut deeply into the underlying granite and allied rocks and the southern boundary of the Nama is a bold escarpment. Although they are outside the limits of the Territory, it is convenient here to describe one or two occurrences which were examined in the adjoining district of Gordonia.

At Riemvasmaak, on the Molopo, the very base of the sediments consists of a few feet of reddish shale. Above come reddish and grey-white quartzites, near the base of which occurs a gritty horizon containing angular pebbles of vein quartz. Save for an occasional thin seam of red micaceous shale or of flaggy quartzites with mica along the parting planes, hard bedded quartzites of the Kuibis type occur to the top of the plateau. These show current-bedding, banding, surfaces with ripple-marks, rill-marks, raindrops, worm-tracks, and mud-pellets, the latter of which on weathering leave shallow rounded hollows on the surface of the quartzites. The thickness of sediments here is about 130 feet; and the beds rest on what is almost an even-planed surface of granite.

Near the top of the road from Riemvastmaak to Narugas (Gordonia) shales and flaggy quartzites are well exposed; here the flags show both broad and narrow ripple-marks abundantly.

On Narugas the junction of the granites and basal shales can be seen in an overflow sluit from the small dam NE. of the house. Near the shales the granite is much decomposed and soft: towards the junction it becomes greener in colour, and the actual passage-beds consist of a soft weathering red rock — a soft breccia containing pieces of red shale, quartz and green chloritic material — which passes imperceptibly into red shales. These, as indicated by one or two siliceous bands, dip steeply away from the granite. The thickness of the passage-beds is about 30 feet. A mass of this soft red breccia about 4 feet long is lying in the shales about 1 foot from their base.

An interesting section occurs on the road from Narugas to Aries (Gordonia). A long, low rounded hummock of granite is surrounded by sand and debris; 30 yards from its edge, shales and flagstones dip away from it in every direction at 25°, a dip corresponding to the upper slope of the hummock. At the top of the plateau (80 feet high) there are horizontal quartzites of the Kuibis type.

The hill on which the Aries Kop Trig. beacon stands displays a structure typical of the relations between the basal Kuibis and the underlying rocks in this area. A hummock of granite is exposed on the south side of the beacon in a small kloof, the top of the hill being formed by a dome of quartzite which dips away from the beacon in all directions. Below the top of the granite in the small kloof an overlap of quartzites on shales can be seen. Lower still, the core of granite disappears, and fairly steeply dipping quartzites form a series of small waterfalls.

Similar occurrences are seen south of the railway between Nakop and Ariams Vlei. Over the flats there outcrop knobs and jagged ridges of gneiss and granite above the true base of the Kuibis beds, the sediments dipping away from the cores of older rocks at angles up to 25°. The very uneven character of the base of the sediments is displayed near Langklip siding (Gordonia) where cores of granite, gneiss and quartz schists rise through the plain and project well above the level of the main Kuibis quartzites to a height corresponding with that of the flat overlying shales. Everywhere the sediments in contact with the cores dip away from the axes of these knobs and ridges.

The basal portion of the Kuibis beds is again well exposed along the irregular escarpment which extends from Blydeverwacht to west of the Ham River on Uheib 84. On Blydeverwacht the escarpment is 650 feet high, of which the top 60—80 feet are formed of horizontal grits, conglomerates and thin sandy shales. The upper surface of the older rocks is peneplaned. On Kentucky the basal beds are about 110 feet thick. The bottom six to eight feet are formed of a coarse quartzitic conglomerate which, on the freshly fractured surface, looks something like the "Banket" and has been prospected without success as a source of gold. Above this are felspathic grits, then thin shales, and then red and blue hard quartzites of the Kuibis type.

Westwards from the Ham river, this southern escarpment becomes less prominent, owing to the gradual rising in altitude of the surface of the granite country south of the escarpment, until at the south west corner of Tsamab it is an insignificant cliff. Here, and on Uheib, the Dwyka tillite transgesses from the Nama on to the granite. The flat area on Tsamab north of the escarpment is formed of Kuibis quartzites overlain partly by Dwyka; and here and there are beautiful exposures of hummocky, smoothed and scratched Kuibis quartzite pavements near the Dwyka boundary.

The most westerly mass of Kuibis seen in this section east of Warmbad occurs on Nieuwefontein Ost 54. Here is a dissected plateau capped by Kuibis quartzites. Around the base of the plateau are outcrops of Karroo dolerite or of Dwyka tillite except in one place where the underlying granite is exposed; and it is apparent that the escarpments bounding the plateau are pre-Dwyka features.

Schwarzkalk. As mentioned above, the base of the Schwarzkalk is taken to be the bottom of the main determining sandstone north of the railway east of Kums, and the base of the first limestone band west of that place.

The beds belonging to the series form a strip along the northern edge of the map extending from the Molopo River in the east to the farm Oab 56 in the west. In Gordonia and as far west as Kums they consist chiefly of thin reddish grey or yellowish quartzites or sandstones and red micaceous shales, and are largely covered with sand. At Kums the basal limestone is a thin band of yellow rock. Above it is a prominent dark blue shale. Above this is a series of soft, rather easily weathered sandstone, in part flaggy, red, buff, mauve and spotted in colour, slightly micaceous and occasionally false-bedded. North of Ukamas these sandstones are overlain by a thin band of coarse grit which, on weathering, has hollows on the surface which were originally probably mud- or sand-pellets.

To the west bands of limestone become more prevalent. North of Gründorn there are several bands of brown-weathering pinkish limestone intercalated with micaceous flaggy shales and thin quartzites, the latter closely comparable in every way with typical Kuibis quartzites. The basal limestone forms the ridge on which stands the southern beacon of Oab 56 just north of the railway; its boundary then turns to the north and passes off the map.

To the west of the Fish river the horizontal Nama covers a large area of plateau-like country culminating in the striking Chumberg. In this area the beds are affected by faulting and by monoclinal folding; similar faulting occurs in the Klein Karas Berg, and has been described and figured by du Toit.*)

The Orange River Area.

In contradistinction to the unfolded Nama of the area described are the several patches of Nama sediments occurring on or near the Orange River between Viols Drift and Chamgabmund, and one or two isolated outliers away from the river. These contain beds which are somewhat highly disturbed; but they are to be distinguished from Rogers' "Folded Nama" of the west, which is certainly pre-Nama in age.

The first area to be considered is that near Viols Drift, where the Orange River has cut a beautiful section through the beds forming the Neint Nababeep Plateau. Rogers has described and figured the sharply folded beds seen on the south bank of the river;**) but his map does not seem to carry the beds far enough to the west.

On the north bank the beds are largely overlain by Dwyka, which transgresses across them on to the older gneisses east of

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*) du Toit, A. L. Geology of S. Africa, 1926, p. 113.

**) The Geology of Part of Namaqualand. Trans. Geol. Soc. S. Africa, 1915, pp. 72—101.

Viols Drift. The Nama beds form a puckered syncline. The Kuibis (Nieuwerust) beds have a thickness of from 200 to 400 feet, and are best seen on the west, where they lie high up on the sides of the north-south range of gneiss hills, the bottom quartzite forming a horizontal capping to some of these hills. In general the Kuibis beds on the west side of this syncline have a high dip to the east. The Schwarzkalk (Malmesbury beds) which consists of limestones with subsidiary quartzites and shales (the latter appearing mainly in the lower part of the series) is highly folded and even overfolded, the steeper limb of each fold being invariably the eastern. The fold-axes strike slightly west of north, and the folds pitch to the north. The beds are here unconformably overlain by Dwyka tillite and have an irregular northern boundary.

The other locality along the Orange river at which Nama beds occur is in the triangular mountain mass bounded by the Orange, the Chamgab and the plain along which the road to Nabas runs. Here the beds have a general steep dip to the east-south-east and are also gently folded. They are divisible into basal Kuibis quartzites and arkoses of not more than 200 feet in thickness, and a great thickness of Schwarzkalk of which the upper half is predominantly formed of blue limestone while the lower half consists of quartzites, phyllites and shales with bands of yellow-weathering limestone and two bands of a limestone conglomerate similar to the type occurring further east at Haly's Drift.

On the east the beds are covered by Dwyka, which is in part faulted down; to the west they are faulted against an older series of sheared sediments, in such a manner that as the fault is traced northwards beds are successively cut out from the base upwards along the fault plane until, at the northern end of the mass, a thin limestone rests on the older sediments, the Kuibis beds having entirely disappeared. The hade of the fault is a low one; the fault itself can be interpreted either as a thrust or as a normal fault of low hade which took place subsequent to the folding of the Nama beds.

The Nama beds of this area and of the neighbouring portions of Gordonia and Namaqualand thus present two types of tectonic features. On the one hand there are the almost horizontal beds of the main mass of the outcrops stretching from north of Upington westwards to beyond the Great Fish River; and on the other hand there are the isolated comparatively highly folded patches of Neint Nababeep, Chamgab and Aiais. The former are affected by normal faulting and monoclinal folding and are cut only by a few dykes of Karroo age. The latter are more highly folded and seen to be definitely associated with intrusions of sub-alkaline rocks. A glance at a small scale map will show that the patches of folded rocks, including those outside the area under discussion, lie roughly along a curved line which is coincident with the line of strike of the folds; and that on this line lie the plug-intrusions of Aiais and Ysterbank and the volcanics of the Bremen massif.

The suggestion is therefore made that the fragments of folded Nama beds of the second type are the remnants of a mass that was let down in something of the nature of a cauldron-subsidence, the sides of which were not vertical but inclined towards the centre of the subsidence, that the folding may have been due to the consequent lateral pressure which would be exerted on the strata; and that the plugs filled with sub-alkaline volcanic rocks, tuffs and breccias correspond with the "rim-volcanoes" that occur along the edge of the cauldron-subsidence of Askja in Iceland.* Much more detailed mapping than was possible would be necessary to prove or disprove the truth of this suggestion. If the ring-fault is present, evidence of it should be obtained in the granite-gneiss tract south-west of Warmbad; the hot springs of Aiais and Warmbad occupy positions which are close to the presumed boundary of this subsidence. A further point that seems to deserve consideration in this connection is the presence of the granite and syenite intrusions of Rooiberg, Kuboos and Tataberg in the Richtersveld and of the Chamgabmund and Bremen at places on, or not far from, the curved line of presumed faulting.

Fossils. Before this survey no fossils had been recorded from the Nama system in this area. In 1925 some obscure impressions were obtained from the shales below Warmvlei Kop in Gordonia. In 1926 similar impressions were got from black shale which had been excavated from a pit alongside the railway at de Villiers Puts, a few miles west of Ham River Station; and some badly preserved Archaeocyathine-like fossils occurred on slabs of red quartzite just below the base of the Schwarzkalk north of Gründorn near the Ham River.

The impressions from Warmvlei Kop and de Villiers Puts are thin ribbon-like markings which curve. They are usually single, but are occasionally apparently branched. One fragment from Warmvlei Kop shows fine longitudinal striae near the edge of the ribbon. All the impressions are crushed flat on the surface of the shale, and it is possible that the supposed branching is really due to the crossing of two fossils. Similar markings from the Cambrian of North America have been considered by Walcott to be flattened worm-trails and referred by him to the genus *Helminthoidichnites*, Fitch. They may be algal in origin, but the weight of Walcott's authority suggests rather that they are annelid.

Undoubted long thin curving worm-burrows occur in a flaggy quartzite north of Gründorn.

Preserved as they are in a rather coarse-grained quartzite, the invertebrate remains from north of Gründorn show very little trace of structure and their true nature is therefore problematical. As preserved they have the appearance of elongated single cups or pipes of circular cross-section, each cup having a somewhat elongated "root" which is bent at an angle to the main body. The outer surface of each body as preserved is furnished with a few longitudinal ridges which seem to carry small knobs regularly arranged. There is also evidence of some sort of cross-walls; but it is impossible to say whether these were external ridges or whether they were septa passing through the body. In general appearance they bear some resemblance to the Archaeocyathid *Coscinocyathus*; but in the absence of structure it is impossible to be definite. It is worthy of remark that Gürich has described a supposed Archaeocyathid from the Otavi Dolomite.*

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* Spethmann, H. Vulkanologische Forschungen im Oestlichen Zentralisland. Neues Jahrbuch XXVI, Beilage-Band (1908), p. 381.

5. PLUG-LIKE INTRUSIONS (PRE-KARROO).

There are in the area under discussion, and in that to the north, a number of intrusive masses which can only, on the field-evidence, be interpreted as plugs. They contain rocks of various types; and, as it is considered that some of these are genetically related to the silver-lead veins of Aiais, they will be described in some detail.

A. North-east of the mining-camp at Aiais, on Levin's Claims 6 and 7, there are three kopjes which appear to be remnants of a ring-shaped mass of quartz porphyry, which at one point is overlain by Dwyka tillite. The kopjes stand on a small sandy plain which is ringed on three sides by hills of schists and gneisses. The occurrence can scarcely be a sheet or dyke and must be considered as an intrusive plug. The porphyry contains phenocrysts of quartz, orthoclase and albite set in a fine-grained granular ground-mass of quartz, felspar and some greenish-brown biotite. The rock encloses masses of pegmatites and schists. At one place it is rather heavily stained with green copper carbonate.

B. North of Bäseke's Camp on Aiais there is another large plug. Two rather prominent kops connected by a nek are formed of a jointed white quartzite, partly brecciated, passing sometimes into grits, and associated with beds of massive yellow-weathering blue limestone. To the east is a wall of white quartzite. Between the kops and the wall of quartzite is an area formed by a bluish-green breccia with a very fine-grained hard matrix. This rock is crowded with inclusions — some of them rounded pebbles and some angular fragments — and looks at first sight like an indurated tillite. This rock is pierced by, and sometimes passes laterally into, a rock containing far fewer inclusions and more obviously igneous matrix. These two rocks cover, with the quartzites and limestones, an approximately elliptical area in which are irregular outcrops of porphyritic lava. On the north and west the area is bounded by the ordinary gneisses and schists of the region which — on the west — have a disturbed zone along the junction. On the east and south-east the rocks are overlain either by patches of Dwyka tillite, which rest indiscriminately against the wall of quartzite or against the breccia, or by gneisses and schists.

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* (Gürich, G. Vermeintliche Fossilien des Otavikalkes in D.S.W.A. Monatsbuch D.G. Gesell., 1913. No. 2.
For reference to *Paramedusium africanum* from Grundoorn, see Gürich, G., Zeitschrift deutsche G. Gesell., 1930, p. 637).

The ground-mass of the breccia is a very fine-grained altered quartz-felspar rock, the felspar being almost entirely changed to calcite and chlorite and, in places, sericite (S.W. 181). The presence of fibrous calcite in considerable quantity proves that the felspar must have been a lime-soda variety. Some of the calcite, together with iron oxides and quartz, is apparently due to the further decomposition of the chlorite (penninite).

The inclusions consist of small angular grains of quartz (which may be broken phenocrysts) and larger pieces of granite, schist, grit and slate. S.W. 183 shows a partially resorbed phenocryst of plagioclase and an inclusion of a fragment of bostonite.

An interesting feature of the mass is the occurrence within it of several patches of ferruginous tufa — almost pure hematite in places — which contain traces of galena, and which are looked upon as solfataric in origin.

C. Opposite Schultz' and Sagner's camp on Aiais are three small hills formed of a coarse volcanic breccia which is associated with porphyritic lavas and with dykes of bostonite. The relationship of this mass to the crystallines is not very clear; but at one edge there is a gradual transition from one to the other through a zone of brecciated gneiss and schists, as occurs in pipe B. The breccia contains numerous inclusions of granite, gneiss and quartzite. On the west this breccia is overlain by the Dwyka.

One section (S.W. 105) under the microscope shows inclusions of granite, quartzite, and bostonite set in a very fine-grained matrix of a low refracting isotropic substance (glass or analcite) containing masses of granular epidote pseudomorphous after augite or hornblende and of anorthoclase. There is a considerable amount of dirty opaque dust and a little apatite. This matrix is obviously allied to the camptonite dykes.

On the south-west side of this mass of breccia, and surrounded by it, is an irregular-shaped body of mineralised rock, consisting of a sandy and tufaceous matrix heavily charged with oxides of iron, wad, gypsum and pieces of brown and purple opal, and cut by stringers of only partially consolidated sandy grit. No lead minerals were seen.

D. About 1½ miles west of this there is an isolated hill showing unusual features. About three-quarters of it consists of a mass of conglomerates, quartzites and altered aplitic rocks with no definite strike, which do not occur anywhere else in the neighbourhood. Associated with these is a green rock composed of stellate masses of green hornblende, brown biotite, subsidiary felspar and abundant iron ore, and containing bands of a harder rock composed of hornblende with blue to green pleochroism, plagioclase, orthoclase, a little quartz, plates of brown biotite, and abundant iron ore. Thin veins of this hornblende rock penetrate the quartzites and aplites, which also carry stringers of the iron ore; and the cracks in the conglomerate and most of the surfaces of the flattened and rounded pebbles in it are coated with a thin film of stellate hornblende.

On the south-east side the hornblende rock abuts abruptly against mica schists, gneisses and aplites in an apparently vertical junction. The whole is pierced by a dyke of bostonite, and is thus presumably of an earlier date than the volcanic breccias which contain xenoliths of bostonite.

The iron ore present in the hornblende rock seems to be martite. It is an oxide of iron, apparently containing a trace of magnesium, is non-titaniferous, very feebly magnetic, with a conchoidal fracture, a metallic lustre, iron-black colour, and a reddish-brown streak. Martite probably occurs always as a pseudomorph after magnetite or pyrites.

6. KARROO SYSTEM.

A. *Dwyka Tillite.*

The beds assigned to the Dwyka tillite in the Warmbad District are of two distinct facies. The one type, the main mass of which is developed in and around the Bondels Reserve, consists mainly of blue-grey boulder mudstones with intercalated shales; the other, which is chiefly confined to the neighbourhood of the Orange River between Viol's Drift and Nabas and the mining area of Aiais, is similar to the brick-red-weathering type briefly described by Rogers from the Richtersveld.*

(a) *Normal type.* The "boulder mudstone" variety of Dwyka tillite covers a considerable area, forming a large part of the country north of a line running from Uheib No. 84 through Tsacharaibes, Luginsland, Hochland and Haib Poort to near Viol's Drift on the Orange River, and west of Nieuwefontein Ost 54 to Gaibes 1. The greater part of the glacial beds in this area occur as boulder mudstone with soft blue or grey argillaceous matrix, except where hardened by igneous intrusions. The inclusions are mostly small, but occasional patches are found where boulders four feet and, more rarely, six feet in length are found. The most common inclusions are of Kuibis quartzites, amygdaloidal lavas, cherts, jasper, porphyry and granite. Shales occur intercalated with the boulder beds and, in places, are also found below them. Owing to intrusions of Karroo dolerite sheets and sills, the rocks are in places considerably altered, becoming harder and lighter in colour. This is particularly noticeable in the calcareous tillite at Drei Kameelbaum, where the normal bluish calcareous matrix has become white and recrystallised. The shales at the same place are baked to a white china-like consistency.

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* Rogers, A. W. The Geology of part of Namaqualand. Trans. Geol. Soc. S. Africa, 1915, pp. 72—101.

This normal type can be studied in numerous localities, short descriptions of a few being given as examples.

At Nieuwefontein No. 54 the tillite is very thin and contains irregular patches of limestone, which are composed in part of gritty masses of gravel. In the northern part of this farm the olive-green and chocolate shales below the tillite showing in the stream beds probably belong to the upper part of the Kuibis beds.

Near the corner beacon of Drei Kameelbaum, Uheib, Tsamab and Nieuwefontein Ost is a striated dome of Kuibis quartzite. Here the striae cross one another. Amongst the boulders seen in this neighbourhood were banded ironstones and Blink Klip breccia from the Griquatown series.

On the south part of Nieuwefontein Ost and on Gross Aub the tillite is not more than 20 to 30 feet thick. It contains very few large boulders, most of its inclusions being small and angular. Associated with it are thin shaly mudstones containing no pebbles. Small patches of gneissose granite protrude through the tillite.

A short distance to the south of Bult trigonometrical beacon on Kalkfontein are good exposures of the greenish shales below the tillite; amongst these shales are thin layers of calcareous sandstone.

In the Bondels Reserve, about three miles to the east of Gabis, the base of the tillite is well exposed. It forms a low escarpment about 10 to 12 feet high resting on granite. A similar feature is seen on Luginsland and Schönau, where a higher escarpment marks the base of the tillite. At the latter places the base of the tillite is very bouldery, many large boulders from the Griquatown and Pniel series being obvious.

West of Kalkfontein, along the road to Guigaib in the Bondels Reserve, the higher ground is generally formed of tillite or shales, the trigonometrical beacons Jacobsplatte and Hugel both being situated on tillite eminences. The whole area here appears to be underlain by a dolerite sheet which shows in the stream-channels; around the hill on which the Hugel beacon stands shales of Karroo type underlie the dolerite.

Progressing to the west, a rise in the surface of the country corresponds to a gradual change from the highly conglomeratic tillite containing many boulders to a mudstone with small and rare inclusions.

In the neighbourhood of Guigaib the tillite is replaced by a well-bedded fine-grained mudstone in which inclusions are small and few in number, the horizontal banding in the rock going over or under these inclusions. This rock may be compared closely with the Varve clays of the Pleistocene glaciation, and suggests deposition in still water. In places here these horizontally bedded mudstones, which contain small grains of quartz, felspar, etc., scattered through them, are contorted and limestones are also present. All the rocks here are highly baked by the intruded dolerite.

At Dreihuk, a few hundred yards to the north of the Native Superintendent's house along the river, are some cliffs about 100 feet high which give excellent sections of the Dwyka resting on the older rocks. Immediately above the gneiss, which is coarse-grained, porphyritic and contains garnets, are about five to six feet of a compact greenish shale; this is followed by four feet of a conglomerate composed almost entirely of angular pebbles. Above the latter come 50 feet of bluish mudstone containing a few small pebble inclusions. The rest of the section is made up of grey and green splintery shales. The matrix of the tillite is sometimes calcareous or siliceous here. At Haib the tillite contains many large boulders, amongst which ancient amygdaloidal rocks are prominent. The boulders here are often four feet long and the rock gives rise to a boulder-strewn veld. The matrix of the boulders is a jointclay, very like many in the Cape Beaufort beds. Large and small phosphatic nodules containing fish-scales and bones are common.

In the south-western corner of Heiragabis, just north of the railway line, occurs a fairly large outlier of Dwyka tillite and shales covering an area 3½ to 4 square miles in extent. Outcrops are scarce and the underground presence of the Dwyka formation is indicated by numbers of large boulders resting on the surface. The tillite has the characteristic grey-blue matrix and contains many large inclusions, boulders 4 feet in length being common. Prominent among these are boulders of Pniel amygdaloids and grits and Kuibis quartzites. A peculiar feature here is the presence of patches of highly calcareous and gravelly tillite. These are more resistant to weathering than the argillaceous varieties, and hence are more prominent. The total thickness of the tillite here does not appear to be very great, as in a well to the west of the dolerite boundary only 40 feet of tillite was penetrated, shales of the Kuibis beds lying below. In further support may be quoted the number of domes of Kuibis quartzite which protrude through the tillite mantle. One of these latter, situated north-west of the Grasvlei trigonometrical beacon, is striated, the direction of the scratches being S. 30° E. The high easterly dip of the Nama under the tillite seems to indicate that this outlier of the Dwyka has been preserved by being deposited in a large fold in the Nama beds.

Half a mile to the south of this occurrence is a small patch of tillite forming a low hill. It rests on the edge of a granite inlier in the Kuibis beds. At Vlissingen, south of the homestead on the road to Kentucky, is a similar patch of Dwyka lying on the boundary of a granite inlier.

The most north-easterly occurrence seen is on Heiragabis north of the road between Ukamas and Spring Puts. Here about 25 feet of baked tillite rest on reddish-weathering green Nama quartzites and are overlain by dolerite. Large boulders are rare, the tillite being a grit with small pebbles few of which are angular and over an inch in length.

Lenticles of green shale occur in the tillite. To the south the dolerite sheet transgresses on to the Nama; and no Dwyka beds are seen in the hills on which the Ukamas trigonometrical beacon stands.

(b) *Red-weathering Type.* This type is practically confined to the area west of the Bondels Reserve and is continued southwards across the Orange River, being well developed there near Nabas and to a less extent south of Viol's Drift. A small outlier occurs on Haakiesdoorn.

The beds consist of thin-bedded sandy mudstones, massive contorted mudstones, flagstones, buff, brown, and pink quartzitic sandstones, and thin siliceous shales with lenticular beds and layers of boulder beds and masses of brown-weathering limestones, sometimes containing grit layers. The boulder beds occur at various levels, whilst throughout the beds small striated pebbles are scattered sporadically. The boulder beds contain beautiful striated boulders and pebbles, large and small, usually of granite or quartzite, closely set in a hard, gritty matrix. Boulders up to four feet in length were observed. The thin-bedded siliceous flagstones are frequently ripple-marked and rill-marked; and invertebrate tracks are very numerous at some localities. The brick-red weathering of the rocks of this variety makes them a conspicuous feature in the areas in which they occur.

The most easterly occurrence of this type — apart from one small outlier far to the north-east on Ukamas and one on Haakiesdoorn — is at Haib Poort, where a thin band rests on a striated surface of fine-grained gneiss. The tillite here consists of buff-coloured sandstones with numerous inclusions. It is overlain by a series of finely-laminated multi-coloured shales which contain no inclusions. Well preserved striated surfaces occur on the underlying fine-grained gneiss.

Westward to Viol's Drift it is apparent that the Dwyka was deposited on a very uneven floor; red and yellow ripple-marked sandstones and mudstones at the base have their bedding-planes conformable with the inequalities of the pre-Dwyka surface. It is noteworthy that in some places the very bottom layer of reddish sandy mudstone adheres strongly to the underlying rock and has its upper surface grooved and polished by ice-action.

Around Klipneus and Nabas on the Orange River the type is well exposed; and there are a number of very interesting outliers occurring in synclinal basins in the Aiais mining area. A noticeable peculiarity of the sandstones is the fact that they weather yellowish-brown with curved layers richer in iron oxides than the rest of the rock, and consequently darker in colour.

The thickness of this type of Dwyka is very variable. Occasionally, as north of Kanibeam, the tillite is altogether absent, and the upper shales overlap on to the gneisses and schists. A few miles away the sequence is about 200 feet thick.

Relation of the two types. What may for convenience be called the "red" and "blue" types of Dwyka tillite in general occupy areas distinct from one another; but occasionally outcrops are found where the relations between the two can be studied.

North-east of the Sjamboks River mouth, in the valley of the Chorab (south of Aussenkehr), the base of the tillite consists of red and yellow-weathering flagstones with invertebrate tracks and crumpled mudstones. These are overlain by blue-weathering boulder conglomerate with large masses of "Gravel Dwyka". Striated surfaces of Nieuwerust quartzites occur just south of this, the striae running north-south.

On the farm Gaibes 1 the usual beds of the Dwyka are built up of a considerable thickness of red and yellow flagstones, ripple-marked sandstones and contorted mudstones with occasional large and small striated boulders. Covering them is tillite with a bluish-green matrix crowded with small pebbles, which passes upward into green and black shales. The same sequence is seen on the road from Gaibes to Aiais. The evidence from the whole area seems strong in favour of the view that we are dealing here with deposits belonging to two distinct ice-sheets, called by du Toit the Namaland ice and the Griqualand West ice.* The deposits from the former are characteristically red-weathering and the glaciated surfaces show that movement was in a north-south direction. The most easterly occurrence of this type is near Ukamas, where pink shales and pebble-beds lie in a small depression on a surface of Kuibis quartzites which is in part plucked and in part striated. The deposits from the Griqualand West ice are bluish-green in colour, contain boulders of far more varying type, and the glaciated surfaces below them have striae running approximately west-south-west (Nieuwefontein, Uheib).

Further, it is apparent that the Namaland ice was the earlier in this region. Wherever the two types are in contact, the boulder-mudstone overlies the "red" type; and the latter never passes upward into the upper shales without some obvious break or the intervention of greenish beds carrying erratics. The passage from the boulder-mudstone into the shales is always a gradual and almost imperceptible one, the inclusions becoming smaller and fewer and the matrix finer-grained and thoroughly argillaceous.

Conditions of Deposition. At Zwartbas, west of Viol's Drift, a most interesting exposure occurs. The Orange River here runs due south for a short distance, and its right bank is a steep cliff formed of mudstones and limestone conglomerate of the Schwarzkalk. These beds are most magnificently glaciated and polished, rounded, channelled and striated — many of the polished faces being nearly vertical. Here and there, against these faces and in small hollows, Dwyka rests. The basal Dwyka consists mostly of yellow impure limestone or shales with very few erratics; but occasionally there is a thin veneer of tillite closely attached to the Schwarzkalk, and in one exposure this veneer (not more than ¾ inch thick) is itself scratched and striated. The tillite here is thin, and some of it dips to the east at about 30°; but a few yards to the north of the section Upper Dwyka shales suddenly come in and lie nearly horizontally.

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* du Toit, A. L. Carboniferous Glaciation of S. Africa. Trans. Geol. Soc. S. Afr. 24 (1921), pp. 188—227.

Similar glaciation of a thin veneer of tillite is seen north of Viol's Drift, and it is obvious that we are dealing here with a succession of advances and retreats of the Namaland ice-sheet, which must have passed over a very uneven surface.

The general nature of the "red" Dwyka precludes it from being considered as a true moraine. The preponderance of flagstones and mudstones, the comparative lack and lenticular nature of the boulder-beds, the presence of ripple-marks and invertebrate tracks, and the obvious bedding all point to the deposition of material in comparatively shallow water, the material itself being in the nature of outwash from the glaciers which, further to the north, deposited their thick moraines in the area south of Gibeon. This outwash must have been largely consequent on the final retreat of the Namaland ice which had previously extended as far south at least as the Orange River; and this retreat must have largely preceded the westward extension of the Griqualand West ice, as formulated by Du Toit. (loc. cit).

The irregularity of the surface over which the Namaland ice moved and on which the outwash material was deposited is very evident, in spite of the post-Karroo warping which has tended to alter its features. One of the most interesting conclusions that has arisen from a survey of the area is that some of the present-day topography of the Orange River valley between Viol's Drift and Kwabs Drift is formed of pre-Karroo features, particularly the prominent cliff of Nama limestone which forms the eastern and northern limits of the Neint Nababeep plateau in Namaqualand.

Rogers has found post-Dwyka faulting south of Viol's Drift; but this faulting is only local and does not extend north of the river — the relations of the Dwyka to the older rocks between Viol's Drift and Haib Poort being those of an ordinary unconformity which has suffered subsequent warping. Again the verticality of some of the glaciated faces at Zwartbas cannot be explained by subsequent warping, and these can only be considered as sides of depressions in the surface of the Nama down which the Namaland ice moved.

Minor irregularities of the surface are fairly numerous. It would seem, too, as if the area of deposition was bounded on the west by the range of hills which run north from the Orange River at Chamgabmund and culminate at Dreikopf; but to the north of that peak the depression in the surface extended westwards at least to the Fish River, as remnants of "red" Dwyka rest on a slightly uneven surface of Nama or of granite on Karious and Geiaus, outside the area under review.

To the east, pre-Dwyka topography is preserved on Nieuwefontein Ost and the neighbouring farms down to the Ham river. In this area tillite of the boulder-conglomerate type rests against cliffs of Kuibis quartzite, with a dolerite sheet cutting both formations. There can be no question of faulting here, and the Nama cliffs must be a pre-Dwyka feature. Elsewhere, as on Heiragabis, peaks and domes of the older rocks project through the Dwyka covering.

B. *The Upper Dwyka Shales.*

As stated above, the "blue" type of tillite passes up gradually into the Upper Dwyka shales. These also overlie the "red" type of the west, but where there is no obvious unconformity (as there is at Swartbas), the two are always separated by a band of blue rock containing boulders and pebbles and, frequently, limestone concretions.

In the area east of Haib the upper shales are not a consistent feature, but, owing to subsequent erosion, are only found in patches on the tillite. They are for the most part soft green and blue, sometimes yellow, thinly bedded mudstones. In places limestone bands are developed.

West of Haib, however, the upper shales cover the tillite altogether for many miles, and reach their maximum development at Eisenberg in the north-western corner of the Bondels Reserve. Here the rocks are yellow, green, grey, pink and blue shales, which break up into irregular fragments; they have interbedded with them lenticles and thin bands of dark-weathering impure limestone — sometimes pyritic — and concretionary nodules which show "snuff-box" weathering. These layers are never more than 2 feet in thickness. Similar but thinner bands and lenticles occur of dark-coloured phosphatic rock, while scattered throughout the shales are occasional small pebbles and nodules. The total thickness of shales at Eisenberg is about 500 feet.

Near Westblik beacon, to the north of Haib, there is a remarkable development of light-blue and grey limestone layers in the shales. These limestones are highly pyritic; and the cubes of pyrites weather into rusty brown prominences on the surface. In this neighbourhood the shales immediately above the tillite are highly folded and much contorted.

The "White Band" forms the top of the Dwyka series. It is composed of very fine-grained thin-bedded black shales which weather to a white colour, especially near the contact with a dolerite sheet. The weathered portions of the outcrop contain thin beds of gypsum. The White Band is particularly well developed in the western part of the district, near Aussenkjer and in and near the valley of the Chamgab. The width of this valley south of Aiais is considerably increased by gentle folding. The identity of this band with the "White Band" of the Union is based not only on its position with respect to the tillite, but also upon the discovery within it at Kanibeam of moulds of the bones of *Mesosaurus* sp.

C. *Ecca Series.*

The Ecca Beds form an area of high ground some 300 square miles in extent between the Chamgab river valley and the Kakab Vlei depression. The area is a plateau-like one with "table-mountains" resting on it; of these, Neidi Berg, Amib Berg (2,690 feet — partly covered with dolerite), and Norotshama Kop (2,818 feet) are the most prominent.

The beds consist of thin yellowish shales which weather brown, green shales, thin limestones — ferruginous in places — sandy shales and, in the upper part, light-coloured sandstones. Yellow-weathering limestones showing cone-in-cone structure are fairly common, and there are in some of the shales large lenticular masses of brown-weathering limestone. Near the base of the beds, south of Gaibes, there occurs a band of massive white chert accompanied by thin limestone.

The Ecca beds are folded into a series of shallow synclines and anticlines. The highest horizon is exposed in the centre of the basin in the Amib Mountains.

Fossil wood, somewhat phosphatic, is fairly common in the beds; but apart from some fragments of unidentifiable bony plates no other fossils were seen.

Fossils.

The Dwyka tillite of the south-western part of the area yielded numerous slabs showing well-preserved tracks of invertebrates. Most of these are of the type usually called "crustacean", and the specimens collected seem to show the presence of several distinct forms. Other markings are more of the nature of the trails thrown out by a boring mollusc or, possibly, by a worm. There was obviously a fairly abundant shallow-water fauna in certain areas, possibly living in pools fed by the mud-carrying streams from the melting ice. That these pools suffered partial desiccation is shown by the presence of suncracks, which do not, however, occur on the slabs carrying the tracks.

Fragments of fossil wood were also found in the tillite.

From the upper Dwyka shales a more definite fauna was obtained. Nodules from the base of the beds near Haib yielded fishscales and a fragment of a large Amphibian (?) bone. From a slightly higher horizon near Haib came a *Mytilus*-like lamellibranch which has been described as *Aphanaia haibensis* sp. nov. by F. R. Cowper Reed*, and the mould of part of a coiled shell which is presumed to be a gasteropod. The same beds also yielded a number of peculiar U-shaped burrows filled with calcite and enclosed in nodular laminated shale hardened with ferruginous cement. Dr. F. A. Bather has identified them as worm-burrows and has compared their mode of occurrence to the U-shaped burrows from the Upper Charmouthian of France named *Tisoa siphonalis*.

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* F. R. C. Reed, 1935, Trans. Roy. Soc. S. Africa.

Nodules from the base of the shales near Viol's Drift contained fragmentary fish, one of which can fairly definitely be assigned to the genus *Acrolepis*. The "White Band" at Kanibeam contained a few moulds of bones of *Mesosaurus* sp.

Fossil wood was found both in the Upper Dwyka shales and in the Ecca beds, being particularly abundant near the base of the latter.

7. THE KARROO DOLERITES.

A particularly striking feature about these rocks in this area is the fact that they occur almost entirely as large horizontal or slightly inclined sheets. The narrow vertical dykes so common in the Union are not represented.

Another interesting phenomenon seen here is that the intrusions are not confined to the rocks of the Karroo system but are found to be cutting the Nama and Older rocks as well. This is very well illustrated in the village of Kalkfontein where a section is exposed showing an inclined dolerite sheet cutting through the older rocks and passing into the Dwyka tillite; a similar section can be seen a mile or so to the south of the village along the motor road to Warmbad. To the S.E. of Bult Trig. beacon dolerite is seen in the old rocks alone.

S.W. of Eisenstein beacon and N. of Guigaib in the Bondels Reserve small sheets of dolerite were observed intrusive in the old rocks.

An exposure at the corner beacon between Uheib 84 and Tsamab 57 shows a dolerite sill lying between the layers of the Kuibis beds. A similar relationship between the dolerite and the Nama is noticed in the stream bed in the central portion of Nieuwefontein Ost 54, while erosion at Drei Kameelbaum 85 has laid bare a sheet of dolerite which underlies the Kuibis beds on the north bank of the stream, and overlies Dwyka tillite on the southern side.

Between Haib and Dreihuk the dolerite is resting directly on the old rocks.

In the eastern portion of the area covered by the map, i.e. the part east of the Ham river, dolerite outcrops are rare, and only small patches of this rock are found generally on the tops of the small hills hereabouts. These patches are in the main formed of a decomposed rock which is often covering thin layers of Karroo sediments as seen in the northern portion of Ukamas and Heiragabis; sometimes, however, the Karroo strata are missing and the dolerite is resting directly on the Kuibis beds, which is well shown in a remarkably good section exposed on the hill just north of Kums Siding.

These isolated occurrences of dolerite apparently indicate the former existence of large horizontal sheets in this part of the country similar to the one now extant at Nieuwefontein. Erosion, however, has lowered the level of the land surface below the base of the sheet leaving only the few remnants quoted.

West of the Ham river the exposed dolerite intrusions become larger and more continuous. On Nieuwefontein Ost 54 and Drei Kameelbaum 85 one sheet extends 16 miles from north to south and is 10 miles wide. Its northern portion has intruded into the Kuibis beds but towards the south it transgesses into the Dwyka series.

In the Bondels Reserve the dolerite sheets cover large areas especially to the south-west of Haib: at the southern end of the Eisenberg hill there is a plug-like intrusion.

A peculiar character noticed in observing these dolerites is the lack of outcrops. Sheets which extend for miles only indicate themselves over large areas by fine gravel and dust debris. Further characteristics of these sheets are their flatness and thinness; none of the dolerites exposed in section was over 100 feet in thickness and the majority were considerably less.

Hardening and thermal alteration were noticed in both the Dwyka and Nama series in the immediate neighbourhood of the dolerites.

West of the Bondels Reserve are two large sheets of dolerite intrusive into the Upper Dwyka shales and forming an almost complete circle round the base of the Ecca beds.

The upper and larger sheet is intrusive into the White Band horizon. It extends from Haibpoort to south of Uhabis in a broad expanse; past this point it narrows considerably running on to Oabib, Nubuorus, and north past Tsawisib to Ourus, forming a continuous dark rampart-like outcrop, with a general dip to the north for a distance of roughly 26 miles. At the latter place the sheet terminates against a fault. About half a mile west of the fault it outcrops again and continues to a point about two miles north of Nabas, a further 8 miles.

Extensions of this sheet, narrow and highly inclined to the east and south-east, are found in the Chamgab valley at Agareibis, Kanibeam, and north of Donas. The exposures at Gaibes, Niederwall and west of Kakab Vlei are less disturbed.

A remarkable feature of this upper dolerite sheet is the fact that it acts as an immense barrier to the underground water stored in the sediments above it. This concentrating effect results in water issuing at no fewer than eight places along the inner margin of the sheet viz. at Gaibes, Donas, Kanibeam, Agareibis, Ourus, Tsawisib, Nubuorus, and Uhabis. Unfortunately, however, owing to the soluble mineral content of the Upper Dwyka shales the water is inclined to be brackish and in some cases unfit for human consumption. This area is otherwise waterless.

The lower sheet occupies a position some 200—300 feet below the upper and extends from south of Nubuorus to a point 3 miles west of Haibpoort. It gives rise to a dark striking outcrop similar to the former.

On the farm Gaibes is a large ring shaped sheet of dolerite in the Upper Dwyka shales, which are highly metamorphosed, weathering out with grey, mauve, and purple colours. This sheet is porphyritic in places, plagioclase forming the porphyritic crystals.

Between Sandrucken beacon and Dreikopf beacon is a small narrow dolerite sheet intrusive in the same horizon.

A narrow dyke about 2—3′ wide composed of fine-grained porphyritic dolerite was observed about 6 miles west of Neidilberg. It is running in a N–S direction. Another dyke about 20′ wide is exposed at the bottom of the hill leading up to Norachas; its direction is a litte E of N to W of S.

In appearance the dolerite which occurs here is the same as that to be seen wherever Karroo beds occur, a dark fine-grained greenish-grey rock.

A typical sample taken at Norachas showed under the microscope ophitic structure with essential plagioclase and augite. About ¾ of a mile to the N.W. of Kalkplatte beacon is an occurrence of a granophyric variety of dolerite. The light-grey rock forms a small body only a few square feet in extent elongated in a N–S direction. It is amongst rock of the ordinary variety.

A sample of this rock showed under the microscope essential quartz, biotite and cloudy orthoclase with a little apatite in small crystals. In places the quartz and orthoclase were intergrown forming micro-pegmatite.

A similar acid rock was observed forming a band in the dolerite south-west of Eisenstein beacon and also on Niederwall Kop west of the Bondels Reserve.

8. POST-KARROO DEFORMATION.

Throughout the basin occupied by the Karroo beds there is evidence of post-Karroo warping. In general the folding produced is gentle. Near the western edge of the area, however, there is a sharp fold with its axis running about N.N.E. and the dip of the beds is up to 70° to the E.S.E. This fold is well displayed in the Upper Dwyka shales and dolerite east of Sandrucken beacon; when traced to the south the fold becomes a fracture with downthrow on the eastern side.

Another fault must be present to the west of Norachas hill. Here there is a difference of level of about 600 feet between the White Band in the Chamgab valley and the same band on Norachas hill. This difference cannot be accounted for by folding, as the beds lie almost horizontally at each place, except that — at the presumed fault — there is a sudden warping and the shales dip at about 60° to the E.S.E., as if they had been dragged down on the downthrow side of the fault. This fault must run through the Kakab Vlei depression and down towards Haib Poort, near which place it brings the upper and lower dolerite sheets almost into juxtaposition.

9. POST-KARROO DEPOSITS.

The only post-Karroo deposits in the area consist of gravel deposited on terraces along certain of the rivers, or of eluvial wash and sand. The only terraces examined were those along the north bank of the Orange river and along the Chamgab (Kameeldoorn) River.

The Orange river terraces occur between Viol's Drift and Zwartbas, north of Aussenkjer, and below the Chamgab mouth. Near Viol's Drift there are two of these terraces, an upper and a lower. The lower occurs along the present bank of the river as far as the Uhabis mouth where it disappears under alluvium and is finally cut off by a bend of the Orange. Several prospecting holes show that the gravels capping it are in places at least 25 feet thick. One such hole showed an alternation of gravel and sand without pebbles. Another showed very coarse gravel with slightly calcareous sand as a matrix.

The upper terrace is highly eroded. It is cut mainly in finely-bedded Karroo shales. It carries some 10 feet of gravel containing a considerable number of large rounded boulders, a foot or so in diameter, with smaller pebbles and coarse sand; the lower 2—3 feet is well consolidated with a calcareous cement. No fossils have been found in these gravels; the pebbles are of the usual "Orange river" type and in consequence a considerable amount of prospecting for diamonds has been undertaken with negative results. The diamonds found amounted to 4.35 carats only.

North of the Chamgab river near Kanibeam there are wide flats covered with silicified and calcified gravel. These flats consist of an old terrace about 10 feet above the present bed of the valley. The gravels are partly overlain by unconsolidated gravel and large boulders, or by sand.

CHAPTER III.

MINERAL OCCURRENCES.

Lead-Silver.

The area which has been prospected for lead comprises the farm Altdoorn 3 (locally known as Ysterbank), — which is outside the area of the map — part of Gaibes 1, and the area south and south-west of these as far as the Chamgab river. In the west the area is mountainous and difficult of traverse, the hills culminating in the points known as Dreikopf and Hochstein; eastwards and southwards the country sinks through a series of foothills to flatter country, which is broken by the line of knobs known as Sandrucken. The hill country is composed of older gneisses and presumed altered sediments cut by pegmatites, diabase and porphyries, and by some intrusive plugs; the flatter country is formed mainly of rocks belonging to the Dwyka series.

Ysterbank is 30 miles by road from the siding at Klein Karas on the Upington — Keetmanshoop section of the railway; Aiais (the chief centre of prospecting operations) is 52 miles from the same siding. The country is barren and has little water. Small supplies of water are obtained from a well in the Kanebis kloof, from the hot springs at Aiais on the Fish river, from Donas on the Chamgab or from Kanibeam spring on the Chamgab. These waters vary in character and in salinity; the best of them is probably that occurring at the hot springs, which are somewhat difficult of access. A fair supply of fresh water is obtainable at Klein Karas. Fuel is rather scarce.

The area is of importance because of attempts that have been and are being made to exploit certain lead and silver-bearing veins.

At Aiais the ores occur in veins which are closely associated with one set of dykes which run rougly 20° North of East; but on Gander's claim 3 and Hänel's claim 6 (Ottosgrund) the veins are not associated with dykes. The veins are narrow and almost vertical; the most prominent mineral — galena — has a varying width in the vein, sometimes being an inch or so wide (rarely more), sometimes thinning out into a mere stringer, and sometimes disappearing entirely. In a trench on Gander's claim 2 a vein of galena 12 inches wide was seen; but such an occurrence seems extremely unusual. Associated with the galena are anglesite and cerussite, with subordinate amounts of calamine, malachite, and chrysocolla; and in some instances gangue material is apparently impregnated with lead, zinc and copper to a small extent.

The veins are mostly fairly short, as far as it was possible to trace them; but occasionally they seem to be of a length of several hundred yards. An occurrence in the hilly country on McCluskie's claim 6 has been opened up practically from top to bottom of a hill-side some 300 feet high. Here the dyke is a red-weathering, greenish-grey quartz bostonite; and on either side of it is a vein with a calcareous matrix carrying galena with patches of grey to black splendent anglesite coated in places with cerussite. The width of galena is variable; but there is no diminution in general width as it is traced from top to bottom of the hill. No occurrence of greater width than 4 inches was seen here; in general it is much less than that, and in places the lode pinches out altogether. Other calcareous veins occur on McCluskie's claims 6 and 7 — of the same general nature as the one described.

Similar veins have been worked on Sagner's claims 4, 6 and 7 and on Hänel's claim 3. On the latter two trenches have been opened near the western corner. Here the lode runs first on one side and then on the other of a dyke of pre-Karroo diabase.

Further towards the south-east development work has been done on two veins of Hänel's claim 6 and Gander's claim 3. Here the galena reached a width of 12 inches at one spot. A surface gossan from Gander's claim 3 consisted mainly of red iron oxide with patches of green malachite and incrustations of cerussite. The whole gossan contained traces of zinc. Other material from the same lode consisted of a dry clay impregnated with anglesite showing concentric structure and in some places of a thickness of a few inches. Gypsum occurred, and thin layers of pale yellow native sulphur — possibly a reduction product from the gypsum. Galena taken from a depth of about 10 feet in the trench had anglesite surrounding the sulphide core in concentric growth, with occasional thin bands of calamine (zinc silicate) in the anglesite.

Specimens of vein material from Hänel's claim 6 were of quartz and iron gossan with cerussite, gypsum, malachite and chrysocolla in small quantities, the iron gossan being impregnated with lead, copper and zinc.

A trench on Raubenheimer's claim 8 shows a gossan consisting largely of impure calcite stained brown in cleavage planes by iron oxide and containing a small percentage of iron and manganese carbonates. This passes into a thin layer of siderite and this into galena and quartz. There are incrustations of colourless crystals of calamine and smithsonite (carbonate of zinc).

Other veins in the area have been opened by trenching; but they all show features similar to one or other of the types described above.

Mr. J. Turnbull, who was for a time in charge of prospecting operations in the fields, has been good enough to supply us with his latest results (1928). They all disclose the fact that, at depths varying from 23 feet to 80 feet in the various cuttings made, the veins of galena vary in width and are never more than from three to four inches wide. One strike, on Raubenheimer's claims 6, 8, 10 and 12, about 4500 metres long, was tested by three shafts A, B, and C. The distance A—B is 800 metres, that from B—C 1600 metres. The shafts are shallow, but disclose from 3 to 4 inches of galena. The galena, however, is apparently not continuous throughout the strike. Mr. Turnbull writes "In all the shafts" "(which include several on Schultz, Sagner and Bäseke's claims)" "as far as the reef has been followed the reef matter has continued" "unchanged in width and composition".

Origin and age of the ores.

That the ores originated from a magmatic source seems undoubted, and a question arises as to which of the various types of igneous intrusion can be considered as being congeneric with the ore-bodies.

The definite association of many of the lodes with some of the dykes would seem to argue that the dyke material should be looked upon as the source of the ores; but against this view there are certain facts which demand notice.

(1) The dykes belong to the two classes of subalkaline (bostonite, camptonite) and non-alkaline (quartz porphyry, quartz keratophyre, diabase) rocks. The lodes are not associated with one but with both of these classes of dykes. None of these dykes have been proved to cut the Nama.

(2) There is evidence to show that the lodes are later in formation than at least some of the dykes. West of the entrance to

Agaraibes Kloof the gneiss-series and the granite are both cut by a three-fold series of dykes of bostonite and other rocks. One of these, running 20° East of north, is associated with irregular veins of calcite up to a few inches in width, of the type that is associated with the mineral veins at Aiais. These veins occur either on the side of the dyke or running through it along the strike of the body; but at one point the calcite vein (which carries hematite) follows the strike of the gneiss and cuts across the bostonite dyke.

(3) On Heley's claims, which lie between Ysterbank camp and the Fish river there are numerous dykes of diabase and porphyritic diabase cutting the gneisses, biotite schists and augen-gneisses. These dykes frequently occur in groups of three or four, and are never more than a few hundred yards from one another. Only one or two carry any marginal calcite or gossan, which — when it does occur — is only an inch or so in width and never shows any sign of mineralisation. Here, too, are veins of calcite running parallel to the strike of the gneisses and cutting the dykes.

(4) In the east of the area under discussion, on the farm Elandsdraai, 21 miles S.W. of Ariams Vlei, recent prospecting has disclosed a lode containing barite, fluorspar and galena with calcite, cutting through a sandstone-conglomerate which forms the base of the Kuibis beds. This conglomerate is overlain by Kuibis quartzites. The lode runs almost due E—W, dips at 85° to the north, and is said to have been traced for a distance of several miles and to have an average width of 2 feet 6 inches. Test holes have not shown the presence of a solid ore body. This is the only known occurrence in the area of a lode cutting any part of the Nama system, although galena has been discovered in patches with barite in pockets in the dolomite (Schwarzkalk) on the Hochebene Plateau near Huns (west of the Fish River) by Mr. Parrott. It must be noted that this Elandsdraai lode differs from those at Aias and Ysterbank in that it is a barytes-fluorite-bearing lode. Of interest in this connection is the fact that in the Freiberg mining area the barytic lead veins are the youngest of the veins.

It may be mentioned here that carbonate lodes with galena were traced by the Survey on the farms Bokiesbank Ost and Blydeverwacht; but these cut nothing later than the older gneisses.

(5) As pointed out previously, there are veins in the older rocks which are unconnected with any dyke intrusion.

On the other hand, there is evidence tending to show a close connection between the mineralisation and some of the intrusive plugs.

(1) At Aiais most of the more important lead-silver veins are clustered within a comparatively small area around the two plugs C and D.

(2) In the plug C occurs a rock actually containing galena crystals surrounded by a thin zone of cerussite; and in the same plug are patches of ferruginous tufa — considered to be solfataric in origin — which contain traces of galena. In plug D, too, is

a similar mass of tufaceous material, carrying gypsum, which is one of the commonest associated minerals of galena in the veins.

(3) The lead ores of Eureka, Nevada, are regarded by J. S. Curtis (Mon. U.S. Geol. Surv. VII, 1884) as the product of solfataric action, in this case replacement in country-rock being effected.

The age of some of the plugs can be determined with respect to the adjacent rocks. Plug C contains a large mass of quartzite and limestone which must be considered as an in-fallen portion of the wall. These sediments are near enough in their nature to the rocks at the junction of the Nieuwerust and Malmesbury series on the Orange River to be looked upon as part of the same group; and the plug is therefore of post-lower Nama, pre-Dwyka age, since Dwyka tillite rests unconformably upon it.

Similarly, plug D — since it includes xenoliths of bostonite — must be considered as younger than the bostonite dykes (which are pre-Nama); but it, too, is pre-Dwyka.

The presumed plug E, however, is cut by a dyke of bostonite and must, therefore, be of earlier origin. The conglomerates which are associated with it must, on the same reasoning, be from a pre-Nama series of sediments.

No direct evidence is forthcoming as to the age of the fourchite — and monchiquite- — bearing plugs which were found on Altdoorn; but if Hacker's theory of the increasing basicity of minor intrusions holds good here, then these may be looked upon as of somewhat later age than the camptonite plug D. Similarly the quartz porphyry plug on Levin's claims should be an early intrusion from the original magma.

The association of lead-silver ores with lamprophyric and allied rocks is known from other parts of the world.

(a) In the Przibram area of Bohemia the genetic connection of the veins with intrusive diorite and its satellites of diabasic and lamprophyric dykes appears to be clearly indicated.

(b) In parts of the Freiberg district dykes of kersantite and minette are plentiful, and the veins are later than these dykes.

(c) In the Vaalpai mining district of N.W. Arizona the rocks are pre-Cambrian granite, gneiss and schist intruded by granite porphyry and by a great number of lamprophyric dykes of minette and vogesite which in part are followed by the veins.

(d) In the Leadville-Boulder country belt the inference that the intrusives are genetically connected with the lead deposits seems well founded, according to Lindgren. "The most abundant"
"intrusions are alaskite porphyry, granite porphyry, bostonite"
"porphyry, monzonite porphyry, and quartz monzonite porphyry."
"The ore deposits are later than the porphyrites but were probably"
"formed shortly after their consolidation. In view of the faint"
"contact-metamorphism effects, it is probable that little if any of"
"the mineral-bearing solution was derived from the small bodies"
"of intruding porphyrites and that the metals were rather derived"
"from deepseated magma basins".

Value of ores.

No special assays have been made for the purpose of this report; but the Inspector of Mines at Windhoek has kindly given certain information respecting shipments of ore which have from time to time been made.

These details are reproduced here.

Ore shipped by Schultz and Sagner:

No. 1 (a) 938 bags of hand-picked galena assayed 72.7% of Pb, 112½ ozs. of Ag. per ton.

No. 1 (b) 1066 bags assayed 74.5% Pb. and 72.4 ozs. of Ag. per ton.

No. 1 (c) 847 bags assayed 73.8% Pb. and 64.1 ozs. of Ag. per ton.

No. 1 (d) 709 bags assayed 73.5% Pb. and 83.2 ozs. of Ag. per ton.

We were informed by Mr. Hänel that samples of ore from Hänel's claim 6 assayed 1.26% of Ag. i.e. 403 ozs. of Ag. to the ton; but we have seen no authenticated figures to support this statement.

Messrs. Lorentz & Bone of Windhoek also supplied us with a table of assay values of lodes on Schultz' claims 6 and 7 and Sagner's claim 8 given by Mr. A. Auret on 31st July, 1926. This table is copied here.

Lode Number	Length of outcrop in feet	Footage sampled	Lode width	Lode Values		Estimated stoping width	Stoping Values		Average depth at which samples were taken
				Lead %	Ag. dwts. per ton		Lead %	Ag. dwts. per ton	
1	600	210	27″	15.1	354.6	38″	10.9	251.0	20′
7	390	20	6″	37.2	695.0	30″	7.4	139.0	8′
8	600	40	28″	3.4	26.1	40″	2.4	18.3	6′
9	360	60	20″	3.4	30.5	40″	1.7	15.8	20′
11	450	100	14″	3.3	62.3	30″	1.6	29.9	12′
15	150	40	15″	10.1	173.7	30″	5.0	86.8	10′
A	20	10	72″	0.4	3.1	72″	0.4	3.1	5′
B	20	10	77″	0.6	6.6	77″	0.6	6.6	10′
16	250	140	21″	6.3	109.6	30″	4.5	78.0	10′
17	280	140	13″	7.8	97.0	30″	3.3	41.5	15′

The values given by Mr. Auret indicate the variability in mineral content of various lodes; they also show the varying width and length of the veins and mineralised zones.

An assay by Messrs. Littlejohn and Whitby, of Johannesburg, on galena obtained from Elandsdraai, gave 84% Pb. and 10 oz. Ag. to the short ton.

Possibilities of the area.

There would seem to be no definite criteria for postulating veins not already discovered; but in general it can be said that the veins tend to strike in a direction approximating to E. 20° N., that they are mostly to be found at the side of dykes, and that they are mostly clustered in the neighbourhood of plug-like intrusions of camptonite and allied rocks.

On the theory of their deposition by ascending magmatic fluids, the veins should continue in depth; but since they are both vertical and narrow, the cost of extracting ore in depth will be considerable. It is to be doubted, too, whether rich argentiferous galena will persist. Experience elsewhere has shown that lead veins which carry zinc ore show a progressive increase in the quantity of zinc present in depth and a corresponding decrease in the percentage of lead. The relative percentage of the two minerals at the surface provides no basis for calculating their relative percentages below; owing to differences in solubility of the sulphates (the products of oxidation), zinc disappears from the upper portions of ore bodies much more rapidly than lead.

Deep mining has not yet been attempted — one or two shafts of about 100 feet in depth being the only development work other than surface trenching; but from the evidence afforded by the lode on McCluskie's claim 7 and on theoretical grounds the veins are not likely to open out when traced downwards, except in an extremely local manner.

In many metalliferous veins, owing to reactions between descending solutions and the primary sulphides, there arises a "Zone of secondary enrichment" just at and below the permanent water-level, which is often the most profitable part of the vein. Unfortunately, we have no information as to the depth at which the permanent water-level is to be found in the area; and it may be doubtful whether, in such a comparatively rainless region as that in which the veins occur, the role played by descending solutions would be a very important one.

The nature of the country rock has also to be considered. In areas where the ascending magmatic waters encounter limestones or similar cavernous rocks there are frequently formed enrichments of ore in pockets in the limestone. At Aiais, however, where the country rock consists of fine-grained schists or gneisses, no such pockets are to be expected.

In our opinion, therefore, it seems unlikely that the production of lead and silver from this area can be profitably increased by more expensive mining on a larger scale. Veins other than those which have been found almost certainly await discovery; but they are unlikely to be of any different nature or to call for mining methods greatly different from those which have hitherto been customary on the fields.

Copper.

Copper ores occur to a very limited extent in narrow veins cutting the old gneiss and associated rocks. The only place in which prospecting work has been carried out to a small extent is on the farm Haakiesdoorn, not far from Goodhouse Drift. Here the ore occurs in quartz veins cutting gneiss. The gneiss is generally altered in the neighbourhood of the veins, becoming highly sheared, siliceous and epidotised. The quartz of the veins is usually white, but in places becomes amethystine.

At hole No. 6 on Haakiesdoorn there is a vein of an average width of 2 feet, expanding in places to 4 feet in width. It dips to the east at 75° and cuts highly sheared sericitised gneiss which, on either side of the reef is silicified and epidotised with a schistose structure. The strike of the vein is at right angles to the strike of the foliation planes of the gneiss. The vein is drusy, and some of the cavities are filled with chalcocite while others contain a mixture of chalcocite and quartz. Elsewhere, prospecting holes shew crushed and brecciated veins with lumps of cuprite and malachite. A number of crush zones in the gneiss, parallel to the veins, shew no sign of copper ores. At prospect No. 14 cuprite has apparently replaced quartz along a thin zone 6 inches wide on one side of a vein, grains of quartz being present in the cuprite in bands. Malachite occurs abundantly.

The following sections of this chapter have been contributed by Dr. W .P. de Kock, formerly Mining Authority to the Administration.

Beryl:

(1) *The Oorlogskloof deposit:* The deposit is situated on the farm Border No. 155, 26 miles from Nakop Siding and within 3 miles of the Union Border. It is covered by a base mineral claim No. 151 pegged by Max Bluhm.

The surrounding country is a plateau, capped with hard brown and red quartzites of the Kuibis series of the Nama system. The Bak river and its tributaries, chiefly Oorlogskloof, have serrated this quartzite capping, exposing the Fundamental Complex below.

The Fundamental Complex here comprises a reddish porphyritic granite, grey porphyritic gneiss passing through all stages of metamorphism into lenses, stringers and remnants of biotite schists. The eruptives and para-gneisses, however, make up more than 99% of the Complex. In the vicinity of the junction of Oorlogskloof and Bak river these granites and gneisses are cut by numerous pegmatites. It is in one of these pegmatite bodies in one of the westerly arms of Oorlogskloof that the beryl occurs.

The country rock is dark biotite gneiss, overlain by Kuibis quartzite. The gneiss is cut by a thick pegmatite blow which curves round in all sorts of fantastic shapes and shoots narrow stringers into the gneiss. The centre of the pegmatite blow consists of massive pale rose quartz. The rose quartz which contains a few books of mica was intruded slightly later than the main pegmatitic mass.

In contact with the quartz the pegmatite becomes a coarse greissen usually very rich in mica, with in places huge blocks of almost pure felspar.

It is in pockets along the contact between the quartz and the pegmatite sections rich in mica, which in addition contain a fair amount of black tourmaline, that the beryl mainly occurs.

In some places sections of the rose quartz are studded with mica, felspar, tourmaline and beryl. This clearly proves that the crystallisation of the beryl is slightly later than the rose quartz, and is to be relegated to the late pneumatolytic phase.

Like most pegmatitic minerals, the distribution of the beryl is extremely erratic. The beryl content of the pegmatite varies from 75% of the total bulk to nothing, within a foot.

In the highly greisenised portion of the pegmatite the beryl is very easy to mine, pick and shovel being sufficient at the shallow depth reached at present.

The pegmatite blow described above extends over a total length of about 200 yards and varies from 1 foot to 60 ft. in width, with an average of about 10 to 12 ft. The felspar is chiefly microcline with subordinate amounts of orthoclase. A light-green to bluish-green colour is characteristic of the microcline where it is greisenised. Unfortunately the pegmatite does not contain beryl along the entire length of its strike but only in a few places. These are described below.

(a) On the eastern bend of the blow a large crystal of beryl measuring 18" by about 7" in diameter showed on surface. It was much cracked and broken and fell to pieces when removed. Only a few other small crystals were found.

(b) South-eastern occurrence. About 30 yards south-west of (a). Here the beryl crystals are large and well shaped measuring up to 1 ft. in length by 6" in diameter. The beryl occurs in greisen of decomposed felspar with lumps of quartz, hardly any tourmaline and coarse mica. A small excavation made to extract the surface beryl measured 20 ft. by 11 ft. average depth. From this 20 petrol cases of beryl were obtained giving an average of 15% beryl in the excavated material. Unfortunately the occurrence is very small, and the rock already shows signs of hardening and the beryl is becoming scarcer.

(c) Main occurrence. This is on the south-western curve of the pegmatite opposite the place where the pegmatite blow attains its greatest width.

A boulder south of the main outcrop composed of quartz, felspar, tourmaline and beryl shows at least 65% of beryl, but it is hard and compact, and it will be almost impossible to extract the beryl from it, as shattering by dynamite usually results in pulverisation of the beryl.

Higher up and alongside of the thick mass of rose quartz, the pegmatite exhibits intense alteration, coupled with extensive development of tourmaline, mica, felspar and beryl. Tourmaline crystals up to 3 ft. in length were noticed; the mica generally is coarse, highly cleavable, of a dirty white colour and semi-transparent. The felspar is chiefly microcline of a light-green colour and where highly weathered it shows a strong filament of lime. Also the beryl crystals which lie in pockets in this highly altered pegmatite are coated with lime.

The mass at surface is soft and friable and therefore easily worked, but the distribution of beryl is extremely erratic.

Five men in 3½ days produced 32 petrol boxes of beryl from an excavation of 40 x 10 x 3 ft. The percentage of beryl in the excavated material was roughly 4%. Subsequent work proved that the beryl-containing greisen narrowed down to a small body of compact rock.

In addition there are stringers of pegmatite cutting into the rose-quartz mass. These stringers sometimes carry a fair percentage of beryl, mostly in perfect elongated sixsided prisms and needles. This beryl could not be produced economically and in any case the quantity procured would be negligible and the cost prohibitive. The colour of the beryl from all these workings varies from light bluish-green semitransparent to yellowish-brown opaque.

Tonnage. As with most pegmatite minerals it is impossible to estimate a definite tonnage. This difficulty is further complicated by the fact that the deposit has not been systematically worked at all. Further the beryl occurs in pockets of irregular outline and limited extent. Up to the present about 16 tons of beryl have been won and sold to the Ore and Metal Company in Johannesburg for export oversea. It now appears that a further 15 to 20 tons is all that could be expected from this property.

On the other hand it is possible that the beryl-containing greisen may extend underneath the Nama sedimentary debris which covers the pegmatite blow to the north-west of the main working and that a considerable quantity of beryl may be extracted from this horizon. In the absence of any work, however, this remains a possibility only.

The method of working the beryl up to the present was very simple, as only surface work has been done. The high mica content and the general state of decomposition allowed of pick and shovel work. The beryl being more resistant to weathering, the crystals were picked out by hand from the loosened debris. It is estimated that a product containing 99% beryl can be obtained in this way.

Henceforth the use of gelignite will have to be resorted to and here difficulties will be encountered that may soon make cost of production prohibitive. If the pegmatite is blasted the beryl cracks and splinters into fragments which are lost. It is therefore essential to use a very low percentage gelignite —

e.g. the type used in coal mines — and drill fairly deep holes, so as just to shake the beryl-bearing rock, and then use stout wedges. In this way the beryl with its usually perfect crystal form and surface polish could be procured as crystals.

Two assays of this ore have been made for the Ore and Metal Company with the results of 11.81% Be0 and 13.60% Be0. This latter result is especially good if we consider that the theoretical maximum Be0 content of beryl is only 14.1%.

Samples of beryl representative of the ore produced from workings (b) and (c) described above, have been analysed by Mr. J. P. van der Westhuizen in the laboratory of the Mines Dept., Windhoek, with the following results:—

Working (b) 20 petrol cases produced, grade 11.2% Be0.
Working (c) 32 petrol cases produced, grade 15.1% Be0.
The value of the ore varies from about £7.0.0 to £10.0.0 per ton f.o.b. Cape Town.

(2) *Haakiesdoorn (a):* About 4 miles from the homestead at Goodhouse Drift and approximately ½ mile off the Goodhouse—Warmbad road on top of the main ridge there occurs a quartz blow of approximately 20 yards by 30 yards. This quartz lens is surrounded by a body of dark flesh-coloured pegmatitic felspar. In this felspar at some distance from the contact with the quartz, crystals of beryl can be seen. The largest crystal is about 2½ ft. long and 7 to 9 inches in diameter. Besides this, three other crystals measuring from a few inches up to 8 inches long were seen in the vicinity. A close search of the surroundings failed to reveal any further crystals and it must therefore be assumed that beryl crystals are sparingly distributed in the felspar surrounding the quartz body.

With the felspar in which the beryl lies there occurs a coarse highly-weathered muscovite which appears to be more prevalent in the immediate surroundings of the beryl crystals. This would be helpful for the cheap extraction of the beryl. The quantity of available beryl is not more than about 60 to 70 lbs. and the property has little or no economic value.

(3) *Haakiesdoorn (b):* To the south-west immediately north of the Orange river an occurrence of beryl has been pegged by Mr. C. Weidner of Goodhouse. The deposit which in general is more or less the same as others described in this report, is almost inaccessible by land. The beryl, if mined, will have to be brought by pack donkeys to the Orange river and from there by boat to Goodhouse. The available quantity is, as elsewhere in this district, extremely limited.

(4) *Haakiesdoorn (c):* Approximately 2 to 3 miles north-west of occurrence (a) described above there occurs a small deposit of beryl crystals on the contact of a quartz lens with pegmatite. The available quantity is small and the deposit of little economic value.

(5) *Goabis:* On the farm Goabis 138 in the Warmbad district situated about 42 miles to the south-west of this town and approximately 8 miles south-east of the Warmbad—Goodhouse road a claim has been pegged by Mr. G. P. Langenegger on a beryl occurrence about 3 miles to the east of Sandberg's house on the road to Sandfontein.

The occurrence lies in a shallow depression where a quartz lens runs zig-zag alongside a little streambed. This lens varies in width from a few feet down to a few inches and can be traced with breaks for a distance of approximately 150 yards. The contact between the pegmatite and quartz is in places made up of a coarse, comparatively soft muscovite greisen which contains considerable quantities of white amorphous kaolin.

In this greisen and closely associated with the pinkish and flesh-coloured felspar there occur nests and crystals of beryl of a glassy-green to dull greyish-green and occasionally bluish colour. The largest crystals exposed measured from 8 to 9 inches in length and up to 5 inches in diameter. Very small crystals measuring only ¼ inch in length were also seen.

Although isolated nests of this material can be traced over a distance of 100 to 120 feet and whilst bits of float were found spread out over the quartz-strewn surface for a considerable distance from the main quartz lens it is very difficult to estimate the exact quantity of beryl available in this property. Insufficient work has up to date been done to prove the exact extent of the larger nests of beryl-bearing pegmatite and even the contact between the quartz and the greisen has not been clearly demarcated.

The cutting made across the quartz lens on the major occurrence of beryl proves that the nests were most erratic and extremely localised.

If all the separate nests and crystals be considered and a reasonable allowance made for continuation below the surface (say 4 to 5 ft.) it may be possible to extract from 2 to 3 tons of beryl.

An analysis of a sample of one of the glassy-green lumps picked up at surface was made by Barclays Bank in February last and gave the remarkable value of 15.23% of Be0. From this it will be seen that notwithstanding the apparently limited quantity available the quality of the ore in this property is of a very high grade.

(6) *Hochfeld (a):* Situated about 1 mile north-west of the farm house and about 18 miles south-west from Warmbad. The geological nature of the occurrence is more or less the same as that of the typical deposits described from other centres and is particularly closely related to the deposit on Goabis described above. The occurrence is on fairly flat country where the only topographical feature is a small quartz lens of about 30 feet in length and 3 to 6 feet in width rising about 10 to 12 feet above the surroundings. Some nice looking light-green

U. OF ILL. LIB.

beryl float was picked up on the slopes of this quartz koppie and approximately 6 crystals of beryl were seen in the contact between the quartz and the pegmatite. These crystals are comparatively small measuring only a few inches in length.

The total available quantity is only a few lbs. and the proposition has no economic importance whatsoever.

(7) *Hochfeld (b):* About 2 miles due south of the homestead there is a further occurrence of beryl which in its geological nature is something out of the ordinary.

An irregular twisted vein of fine-grained aplitic gneiss which in texture almost resembles a compact quartzite can be traced at intervals over a distance of several hundred yards. The vein runs more or less in the centre of a ridge which stands out from the surrounding porphyritic altered granites.

On this ridge in the zone described above small lenses of quartz and felspar occur and with them a certain percentage of green microcline and occasionally crystals of beryl. Sometimes massive lumps and veins of beryl can be seen. Some of the quartz adjoining these minerals is also impregnated with finely disseminated beryl and felspar. It is extremely difficult to distinguish between the light-green beryl of massive texture and the green microcline where both are of more or less the same colour. The available quantity is most difficult to estimate on account of the obscuring effect of the microcline. Moreover no work has been done and the property has not been opened up in any way. The result is that it is almost impossible to gauge the depth to which this deposit might go down. From the material seen at surface it may be possible to collect from ½ ton to 1 ton of beryl.

From what I have seen of this proposition it appears to warrant expenditure for proving the extent of the deposit both on the strike and in depth.

Corundum:

An occurrence is located about 7½ miles west of homestead on the farm Hochfeld No. 112, to the north of the direct road from this farm to Sandfontein.

The country is fairly flat and open, with shallow sand rivers or rivulets running from north to south.

The country rock is biotitic gneisses, varying from sheared granites through ortho-gneisses to para-gneisses and migmatites. In this comparatively acid base there occur numerous lenses of biotite schists and other foreign rock units which have been incorporated but not assimilated by the original granitic magma.

These exogene lenticular inclusions have been intensely altered and not infrequently completely metamorphosed.

In the vicinity of one of these lenses of dark biotitic schist numerous crystals of corundum were discovered. On tracing the "float" the biotite schist was found to be the parent rock from which the crystals of corundum originated. The crystals in the parent rock are masked by a film of mica and usually occur as mere swellings on the foliation planes of the fissile schist.

The corundum-bearing schist occurs in close proximity to abundant veins and lenses of quartz. Although fissile the schist is extremely tough and difficult to break across the planes of schistosity. This phenomenon is responsible for the fact that the comparatively soft schist is not eroded deeper than the harder and generally more compact gneisses and quartz, and can be accounted for at least partly by the interlocking pattern the corundum crystals and needles develop in the schistose matrix.

The corundum-bearing lens can be traced for just over 100 feet, and at both ends separate small lenses tail off into the gneiss. The maximum width of the main lens is about 3 feet and the minimum a few inches, the average width being about 12" to 18". The lens strikes south-south-west by north-north-east and dips to the north-west at about 60°, the angle of dip coinciding with the planes of foliation in the schist.

The corundum occurs in appreciable quantities, sometimes constituting at least 50% of the bulk of the rock. The crystals generally lie with their long axes at right angles to the foliation planes of the schist and less frequently obliquely thereto.

The size of the crystals varies from mere splinters to crystals of ½" in diameter, while the length is from ¼" to 3".

The colour is generally greyish, greyish-brown to a delicate pink or flesh colour when clean. On the northern extremity of the lens some splinters of a deeper pink were found almost with sufficient colour to be compared with some of the massive semi-precious corundum from Barberton.

On the slope below the reef there occurs a considerable quantity of float, which is generally free from adhesive impurities.

The quantity of float that can be collected is about 200 to 300 lbs. The corundum obtainable from the reef is of course far more abundant, but it will be an extremely difficult and costly process to separate the cyrstals from their matrix with any degree of purity.

The quality of the corundum appears to be equal to the best Transvaal material.

The extent of the deposit is not such that it has any economic importance, but it is interesting since this mineral is of apparent rare occurrence in the Territory.

Fluorspar:

On the farm Platrand about 20 miles south-east of Ariamsvlei Station there occurs a series of narrow veins and fissures in the Kuibis quartzites of the Nama system. These veins are sometimes filled with quartz crystals growing on one and both walls of the fissure and pointing inwards with their pyramid apices. Usually these quartz crystals are embedded in a base of amorphous chalcedony. The fluorspar is found intergrown with the quartz and generally filling the central portion of the fissure.

It varies from a massive type in which hardly any crystal form can be made out to perfectly crystallised cubes and octahedra of a delicate green to deep-purple colour. It is doubtful whether more than a few tons of fluorspar could be obtained and the product would at best be very impure. The occurrence therefore has no economic importance.

Rose Quartz:

Some of the massive pegmatitic quartz blows in the Orange river valley and more especially those in Bak river contain considerable proportions of light pink to deep rose coloured quartz. In the north-western tributaries of Oorlogskloof there occur a few massive bodies of rose quartz with sufficient colour to be used as ornamental semi-precious stone. Unfortunately the quartz is generally badly cracked and the colour is not uniform even in comparatively small blocks. In addition inaccessibility and transport difficulties may prove serious handicaps to exploitation.

CHAPTER IV.

WATER SUPPLIES.

The area is one of very low rainfall and with the exception of the Orange river there are no perennial streams; accordingly the majority of the inhabitants depend entirely on underground water for their needs.

There are very few natural springs and these are separated from one another by great distances. Farms situated in between these springs depend on opening up underground supplies.

Water in sand and alluvium in sand-filled valleys. Subsurface water seems to be flowing in the sand and alluvium in the dry river beds, and has been obtained at Ukamas where several shallow wells sunk in the alluvium near the homestead have large supplies of fairly fresh water. At Kums on the north side of the railway line salt water is issuing from the alluvium.

At Haib wells sunk by the Bondelswarts natives in the alluvium of the Haib river tap supplies of fresh water. At Rosynbos near the Fish river a small quantity of water is obtained in a well sunk in alluvium.

Springs. At the Mission Station on Heiragabis a shallow well sunk in the Nama beds (Schwarzkalk) seems to tap a large supply of water in a limestone layer. This stratum which is only 5—6′

thick apparently acts as a subterranean reservoir for the 200′ or so of shales and quartzites above it. At Jerusalem water comes out of joints in a coarse-grained garnetiferous aplite near its junction with the gneiss.

In the Chamgab river valley several small springs issue in places where dolerite sills cut the shales of the Dwyka series, notably at Gaibes, Donas, Kanibeam and Agareibis. These supplies are highly mineralised, containing a high content of magnesium sulphate and accordingly are not potable. The mineral content is presumably derived from the White Band shales through which the water percolates.

The large dolerite sill which extends from Ourus through Nubuoras to Uhabis causes water to appear at the surface at Urus, Tsawisib, Nubuoras, Oabib and Uhabis.

Hot Springs. At Warmbad large quantities of warm water issue from the gneiss.* Just below the point at which the water appears the surface level of the gneiss drops about 15′ forming a ridge. To the west of the bath house at a distance of 100 yards fine-grained granites have been intruded into the gneiss, both rocks being subsequently invaded by pegmatites.

The temperature of the water when it comes out is about 100° F. and it is highly mineralised, containing sodium chloride, sodium sulphate and calcium sulphate. Large quantities of gas accompany the water and proved on analysis by Versfeld to be mainly nitrogen. The smell seemed to indicate the presence of sulphur dioxide.

In the Fish river, hot springs are situated at Groot and Klein Aiais. The former place was not visited but at the latter the water was found issuing from the gravel and alluvium in the river bed; the rock exposed nearby is a dark argillaceous schist. The water is mineralised to a greater extent than that of the Warmbad spring and the temperature at the spring is 131° F. At Blydeverwacht a spring issues from the sand on the river bank about 20′ above the bed; a reef of amphibolite cutting N—S across the sheared gneisses seems to determine the place of outflow. The water is warm and the quantity is estimated at approximately 40,000 gallons per day.

At Gründorn about 2 miles to the north of Ham River Station a warm spring comes out of a small inlier of gneiss in the Zwartmodder beds. The quantity of water flowing here is small but it is accompanied by an inert gas.

At Dreihuk in the Bondels Reserve large quantities of water issue from gneisses exposed in the river bed. This water is not thermal but is highly mineralised.

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* Versfeld, W. The Geological structure of portions of German South West Africa. S.A. Journ. Sci., 1915, p. 227.

Boreholes.

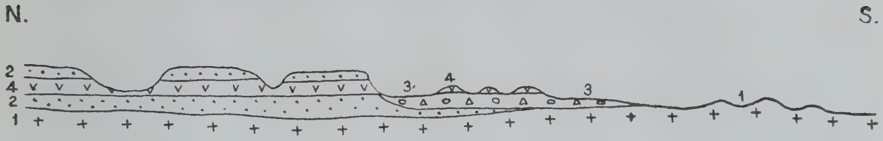
Very little drilling has been done in the rocks of the Dwyka series and large supplies can hardly be expected from this formation as it is so thin.

West of Haib it will probably prove a better water carrier as the number of springs which issue from it seem to show. The water from these springs, however, is in practically every instance brack.

Records of boring in the Nama beds show that fairly good results can be obtained here, especially when the basal beds and the underlying rock are penetrated. These beds lie on an uneven floor of older rocks and have proved themselves to be good water-carriers.

Decomposed areas in the granites and gneisses which are known to hold underground water are difficult to locate and when found they do not seem to be of great extent. In fact in some areas they seem to be absent altogether. The evidence of the large springs issuing from these rocks proves that vast quantities of water must collect and circulate beneath the surface, but the difficulty of locating the subterranean whereabouts of this water from surface indications makes boring for water in these rocks a matter of speculation.

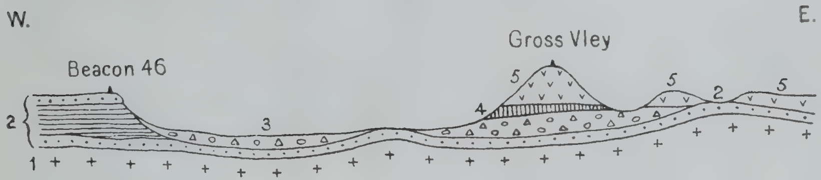
Generalised Section across Nieuwefontein Ost.



1. Granite. 2. Kuibis Beds. 3. Dwyka tillite. 4. Karroo Dolerite.

Fig. 1.

Section across Heirachabis.



1. Granite. 2. Kuibis quarzites and shales. 3. Dwyka shales.
5. Karroo Dolerite.

Fig. 2.

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GEOLOGY

RECENT

A

Wind blown Sand

SYSTEM

D

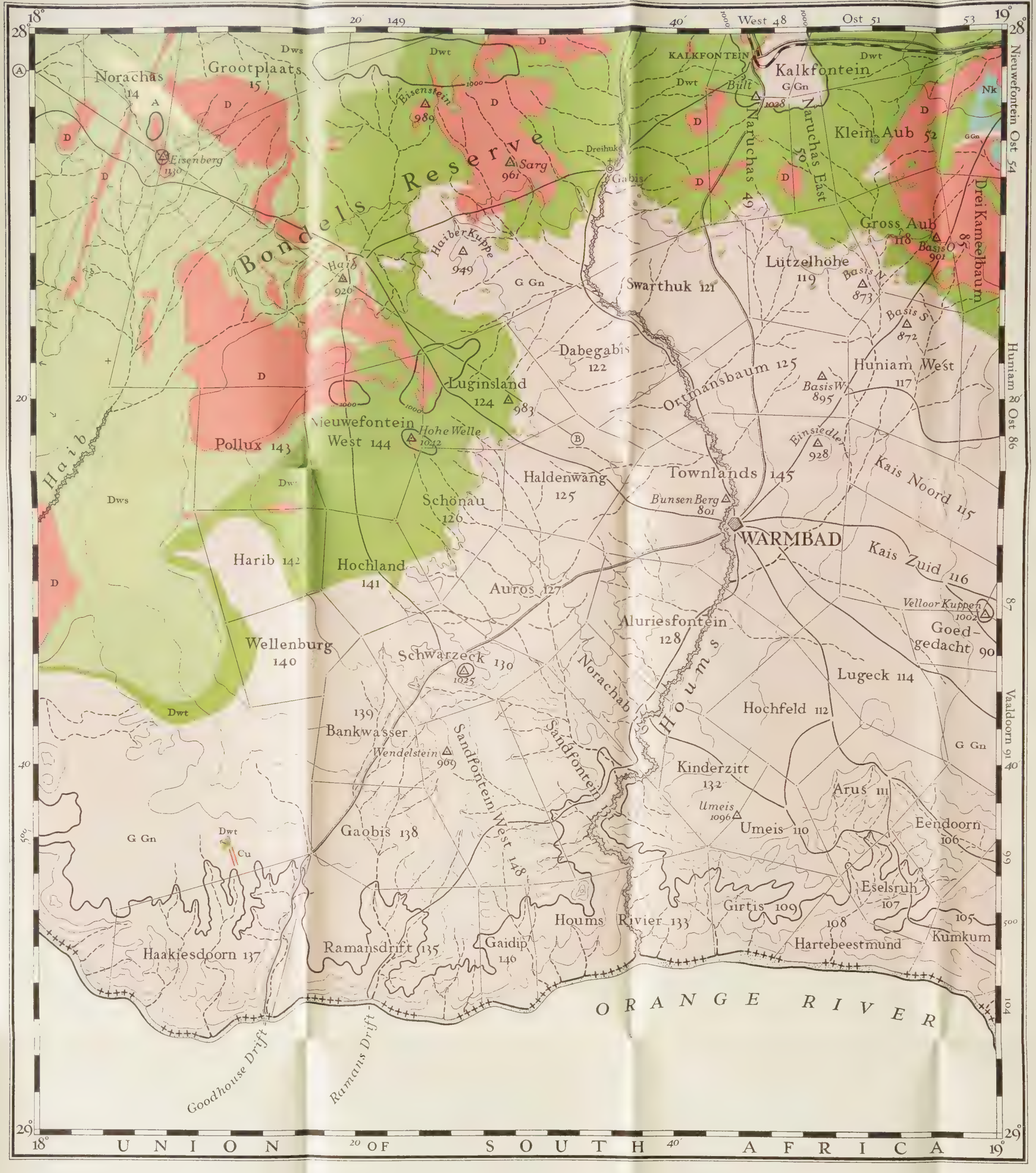
Dolerite sheets and Dykes

Dws

SOUTH WEST AFRICA

UMEIS

S.H-34-A



GEOLOGY

RECENT

- A Wind blown Sand

KARROO SYSTEM

- 🟥 D Dolerite sheets and Dykes
- Dws Dwyka Shales
- 🟩 Dwt Dwyka Tillite

NAMA SYSTEM (Lower Division)

- Nk Kuibis Beds Shales, Quartzites and Conglomerate

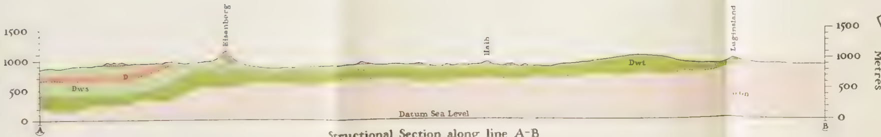
ARCHAEAN

- G,Gn Granites and Altered Sediments
- Cu Copper Lodes

- Boundary
- Dip and Strike
- + Horizontal Sediments

TOPOGRAPHY

- ++++ International Boundary
- Farm Boundary
- Main Roads
- District Roads
- Station Railways
- Rivers (mostly dry)
- Towns
- △ Trigonometrical Point
- Mission Station
- Contours



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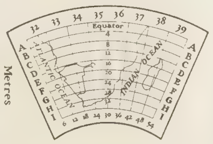
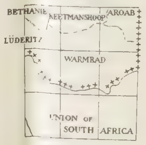
International Key
Africa South of Equator



Isohyete Diagram



Sheet System

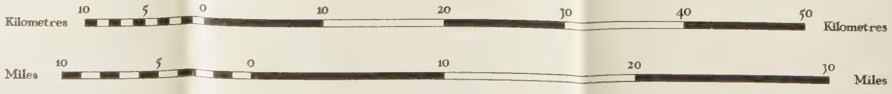
A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
S	T	U	V	W	X

Adjoining Sheets

HUMS SG-33-X	KARRAS SG-34-S	OAS SG-34-T
AMIB SH-33-F	18° 30' E 28° 30' S	NAKOP SH-34-B
SH-33-L	SH-34-G	SH-34-H

Geological Survey. South West Africa
S.H.Haughton B.A., D Sc. Senior Geologist
H.F.Frommurze B Sc. Geologist

1:250000



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GEOLOGY

ROO SYSTEM

D

Dolerite sheets and Dykes

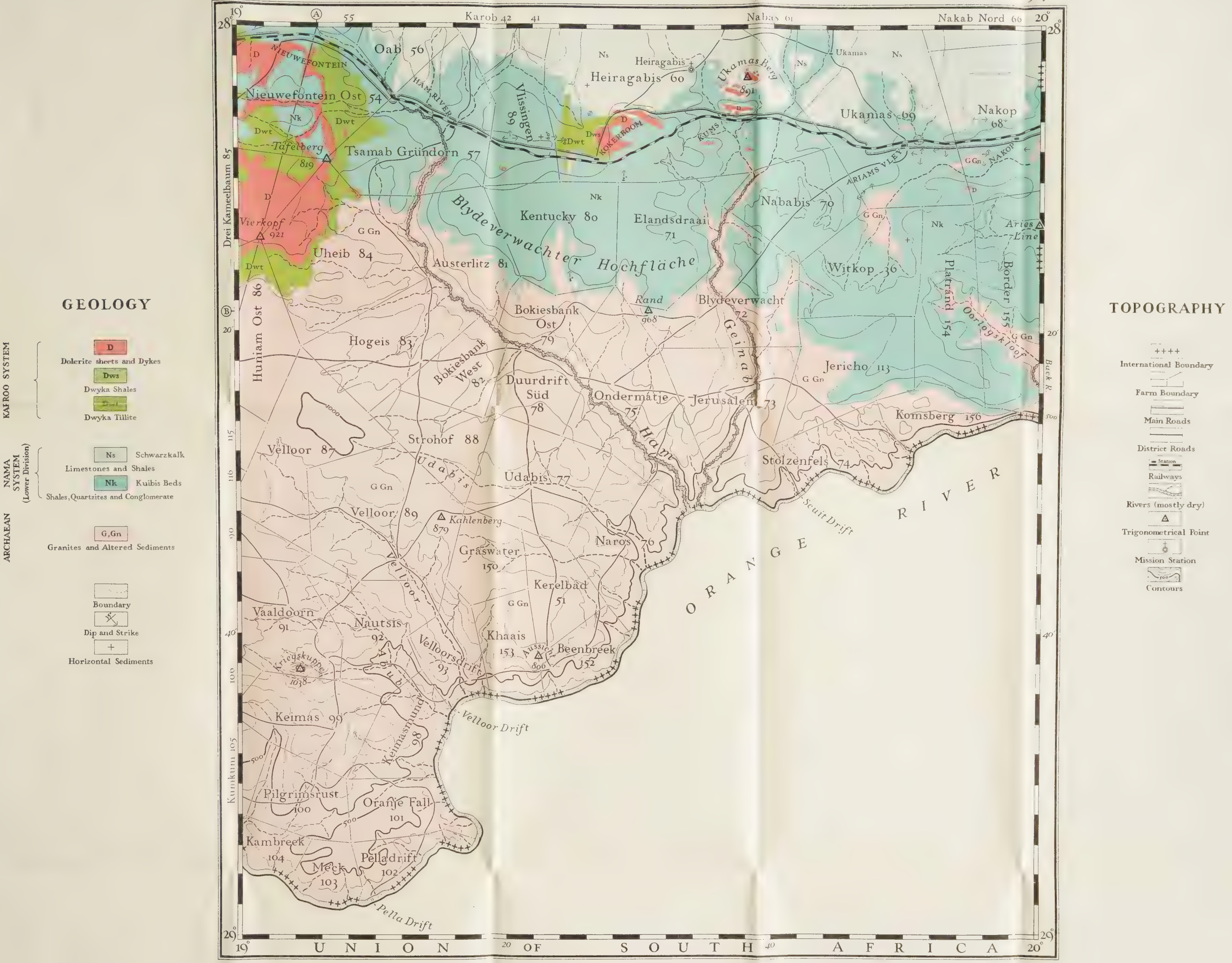
Dws

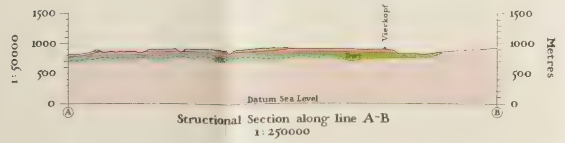
Dwyka Shales

SOUTH WEST AFRICA

NAKOP

S.H-34-B





Structional Section along line A-B
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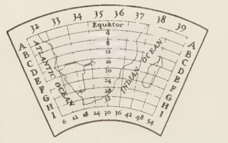
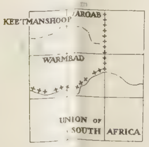
International Key
Africa South of Equator



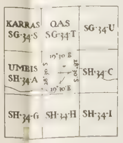
Isohyete Diagram



Sheet System

A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
S	T	U	V	W	X

Adjoining Sheets



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H.F.Frommurze B Sc. Geologist

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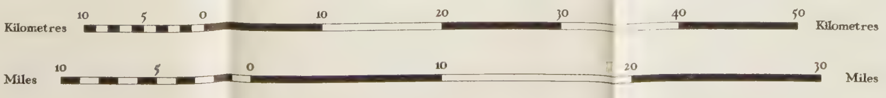

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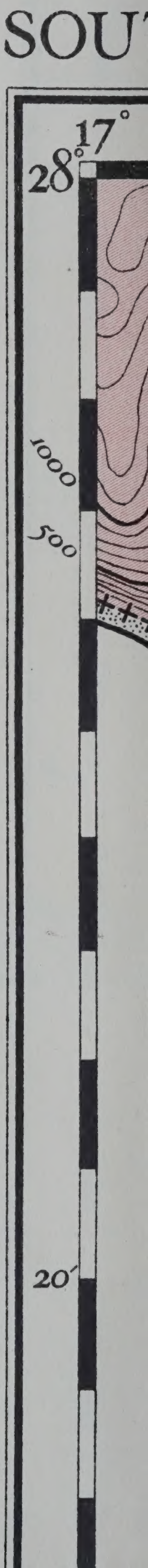


GEOLOGY

RECENT

A
Wind blown Sand

Alluvium and Gravels

KARROO SYSTEM

D
Dolerite sheets and Dykes

Ec
Ecca sandstones and Shales

Dws
Dwyka Shales

Dwt
Dwyka Tillite

NAMA
YSTEM
ver Division)

Ns Schwarzkalk
Limestones and Shales

Nk Kuibis Beds

SOUTH WEST AFRICA

AMIB

S.H-33-F

GEOLOGY

RECENT
- A — Wind blown Sand
- Alluvium and Gravels

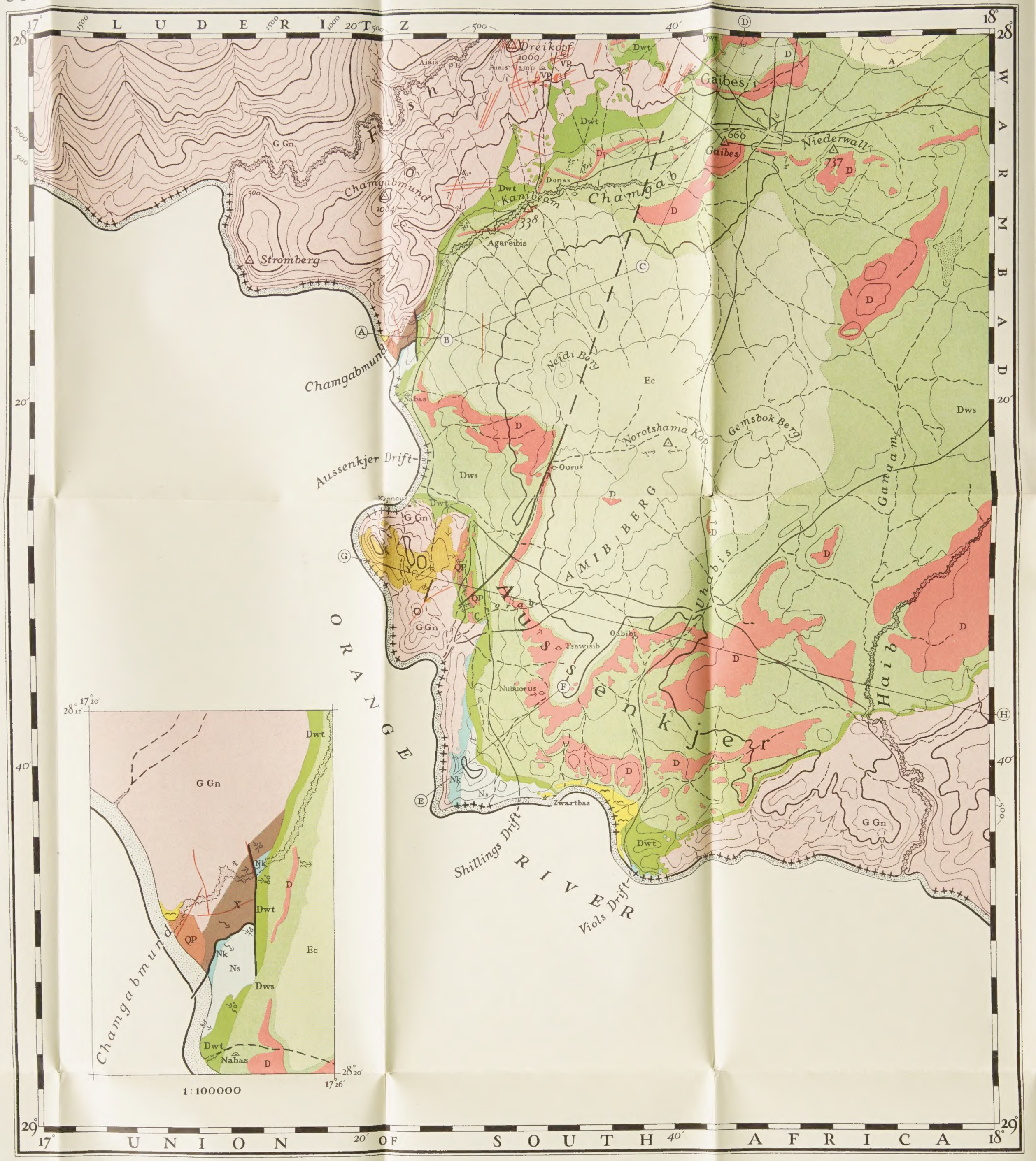
KARROO SYSTEM
- D — Dolerite sheets and Dykes
- Ec — Ecca sandstones and Shales
- Dws — Dwyka Shales
- Dwt — Dwyka Tillite

NAMA SYSTEM (Lower Division)
- Ns — Schwarzkalk Limestones and Shales
- Nk — Kuibis Beds Shales, Quartzites and Conglomerate

KONKIP SYSTEM (?)
- X — Numees Beds Slates, Arkoses grits with Tillite
- Y — Stinkfontein Series Quartzites

ARCHAEAN
- G,Gn — Granites and Altered Sediments
- VP — Volcanic plugs and dykes
- QP — Quartz porphries

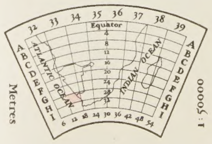
- Fault (revealed)
- Fault (concealed)
- Folded Beds
- Dip of shear Planes
- Boundary
- Dip and Strike
- Glacial Striæ Occurrence (ø28°42′ λ17°32′)

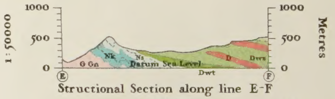


TOPOGRAPHY

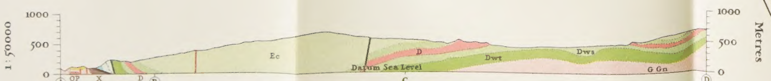
- ++++ International Boundary
- Farm Boundary
- District Roads
- Rivers (mostly dry)
- △ Trigonometrical Point
- Contours
- Hot Spring
- Water Hole (Spring)
- Water Hole
- ▬ House
- Huts

International Key Africa South of Equator





Structional Section along line E-F
1:250000



Structional Section along line A-B-C-D
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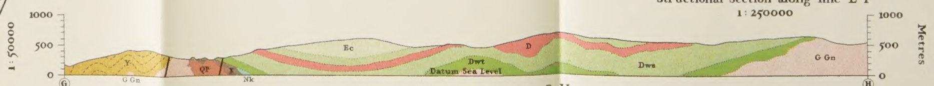

Structional Section along line G-H
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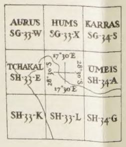
Isohyete Diagram

Sheet System

A	B	C	D	E	F
G	H	I	J	K	L
M	N	O	P	Q	R
S	T	U	V	W	X

Adjoining Sheets



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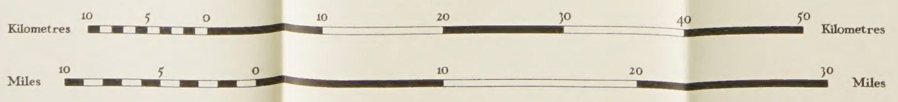

1935

ERRATA.

(1) In the geological reference table on the Amib sheet, the word porphries should read "porphyries".

(2) The colour of the two dykes — one a north-south dyke west of Neidi Berg, and the other a dyke north-east of Niederwall — on the Amib sheet should be shown as Karroo dolerites.

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